MINERAL RESOURCES OF REWA STATE, C.I.

BY

KAIKHUSHRU P. SINOR, M.A., B.Sc. (Bombay),
A.R C.S., A R.S.M., D.I.C. (London).

State Geologist, Rewa State.
Formerly State Geologist, Bhavnagar State.

Published by order of the Rewa Durbar.

CALCUTTA:

PRINTED AT THE BAPTIST MISSION PRESS.

1923.

TO

HIS LATE HIGHNESS, COLONEL SIR VENKAT RAMAN SINGH BAHADUR, G.C.I.E., MAHARAJA OF REWA, WHO TOOK A KEEN INTEREST IN THE DEVELOPMENT OF THE MINERAL RESOURCES OF REWA STATE, THIS BOOK IS RESPECTFULLY DEDICATED.

PREFACE.

In the area of 13,000 square miles which Rewa territory covers, most of the important geological formations of Peninsular India are met with. In fact, the geology of Rewa State is an epitome of the geology of India. Such being the case, it is not to be wondered at that important economic mineral deposits occur within Rewa territory. It may also be stated that there is every possibility of fresh minerals being found in Rewa State, both, in the old crystalline formations consisting chiefly of gneisses and associated rocks, and in the metamorphic rocks of Bijawar age which cover hundreds of square miles; as, many minerals not yet found in Rewa State are known to occur in other parts of India in similar formations.

The great drawback to the successful mineral development of Rewa State is the absence of good roads and railways. With the exception of the Katni-Bilaspur branch line of the Bengal Nagpur Railway, which partly runs through a short strip of Rewa territory in the southern part of the State, there is no railway in Rewa State. I earnestly hope that His Highness the Maharaja Sahib Gulab Singh Bahadur and his advisers will devote their early attention to the construction of railways and good metalled roads in Rewa State.

This book is divided into four parts:—

Part I. Rewa State Coal-fields.

Part II. Rewa State Corundum.

Part III. Limestones, Iron Ores, Ochres, Fire-clay, and Minor Minerals.

Part IV. Possibility of Manufacture of Aluminium in Rewa State.

Only a short while ago these parts were published separately. In this book all the four parts are grouped together with a view to place before the public a brief account of the minerals known to occur in Rewa State at the present time.

KAIKHUSHRU P. SINOR.

CONTENTS.

Part I. Rewa State Coal-fields.

Part II. Rewa State Corundum.

Part III. Limestones, Iron Ores, Ochres, Fire-clay Deposits, etc., etc.

Appendices.

LIST OF PLATES.

LIST OF MAPS.

PART I.

REWA STATE COAL-FIELDS.

INTRODUCTION, PART I.

The coal-fields of the southern part of Rewa State first received detailed attention at the hands of Theodore W. H. Hughes to whose clear vision as a geologist and to whose persevering and indefatigable nature our present knowledge of these fields is chiefly due. He was the first to point out the true age of the coal-bearing strata near Umaria which had been assigned by another geologist to the "Jubblepore" or upper Barakar horizon. The results arrived at by him during the survey and exploration of the different coal-fields were published by the government in Vol. XXI, part 3, of the Memoirs of the Geological Survey of India. Unfortunately, this book is out of print and not available to the public.

During the 38 years which have elapsed since the publication of the able memoir on the coal-fields of Rewa Gondwana Basin written by Hughes, parts of the Sohagpur coal-field near the railway stations of Burhar, Sohagpur, and Anuppur have been again and again prospected with the result that very thick and workable seams of coal have been found near Dhanpuri, Semra, and adjoining places. A keen desire is at present being shown by both local men and residents abroad to prospect and carry on systematic mining work in accessible parts of the Sohagpur and Johilla coal-fields.

Besides the four coal-fields—Umaria, Korar, Johilla, and Sohagpur—described by Hughes, there is another known as Singrauli, in North Rewa, from its proximity to the Singrauli Ilaka on the western border of the Mirzapur district. It appears as if this coal-field will also come

into prominence in the near future as there is some serious talk of the construction of a railway line connecting the East Indian Railway somewhere near Sone East Bank with the Katni-Bilaspur branch line of the B.N. Railway. The Engineer-in-chief of the Central Indian Coal-fields Reconnaissance Survey has already carried out the necessary preliminary survey. It is possible that the route selected would develop parts of Sohagpur and Singrauli coal-fields both.

For these reasons, I have thought it advisable to write these notes on Rewa State coal-fields in the hope that they might prove useful to those enterprising men who would like to develop any particular area in one or other of these coal-fields. In the preparation of these notes I have largely drawn upon Hughes' memoir, particularly regarding the early development of the Umaria coal-field and the preliminary exploration of the Korar, Johilla, and Sohagpur coal-fields; also, descriptions of outcrops which I had not the opportunity of examining personally. It would not be out of place to mention here that Rewa State owes a debt of gratitude to the Government of India for having lent the services of an able geologist in the person of Mr. Hughes and for having supplied the necessary 'sinews of war' for getting the different coal-fields properly examined by borings, shafts, and tunnels.

I would recommend readers of these notes to consult maps on the scale of 1 inch = 1 mile, to enable them to find out the exact location of any particular outcrop or outcrops for which latitudes and longitudes are in most cases given. As the coal-bearing area covers hundreds of square miles it has not been found feasible to attach these large scale maps. To show the general outline of the different coal-fields a small map on a scale of 1 inch = 8 miles is attached.

PART I.

REWA STATE COAL-FIELDS.

I. Historical Notes, Umaria Coal-field.

True geological horizon of the Umaria coal.

The ground near Umaria had been examined as far back as the year 1859 by Mr. J. G. Medlicott of the Geological Survey of India. On the geological map then published Umaria (Omria) was placed on the same horizon as the lower Damuda, i.e. the true coal-measure rocks (Memoirs II, part 2, p. 171). The upper Gondwana beds of a later epoch which are well exposed on the Mahanadi River near Chandia (Lat. 23° 40′; Long. 80° 45′) had not however been differentiated from the lower Gondwana beds nor were the beds older in age than the lower Damuda, namely, the Talchirs, clearly recognized in this area. In 1868-69 Mr. B. Medlicott first detected the Talchir rocks north of Umaria not far from the village of Lora. In 1871-72 Mr. Hacket was entrusted with the work of mapping various parts in southern Rewa territory but he failed to distinguish the Barakar beds from the Jabalpur or the supra-Barakar beds, all the rocks being designated by him to the upper or Jabalpur horizon. In 1881, Mr. T. W. H. Hughes was deputed by the Geological Survey of India to examine and map the southern part of the Rewa territory. He was the first to point out that the Umaria coal was of Damuda age, and not of upper Gondwana age. The discovery of fossils by his colleague Lala Hira Lal, strengthened his conviction as to the true horizon of the

coal-bearing beds. This point being confirmed, he commenced his investigations and proved the existence of four different coal-fields—Umaria, Korar, Johilla, and Sohagpur in Rewa territory, and three others in adjoining parts which he named Kurasia, Koreagarh, and Jhilmilli. Having satisfied himself that the rocks at Umaria belonged to the coal-bearing horizon proper he set to work assiduously and in a thorough manner, and in a short time proved the importance of Umaria and Pali as coal-bearing centres. Captain Barr was at that time Political Agent of Baghelkhund and Superintendent, Rewa State. Mr. Hughes approached him with an appeal for financial help, so as to enable him to determine positively the value of Umaria coal-field. In Memoir XXI, part 3, of the Geological Survey of India Mr. Hughes makes some very complimentary remarks about Captain Barr who promptly gave him financial help, and assisted the investigating party in a number of other ways. He says: "In securing and moulding labour we should have been perfectly helpless without Captain Barr's help and the end of our researches would have been in the far future instead of having its termination in the season 1883-84."

First notice of seam of coal at Umaria.

The original discovery of this coal dates as far back as the year 1860 when Captain Osborne who was then Political Agent at Rewa drew attention to it. At his suggestion Mr. Alexander Grant of the East Indian Railway and Captain Hyde, R.E., consulting engineer for Railways visited Umaria and other localities where coal had been found. They formed a rather poor opinion of the coal seams and did not think it worth while to have the field properly explored. From the report submitted by Mr. Grant it is clear that the value of the

Umaria coal was much underrated. He stated: " The seam shows itself in four different places in the bed and side of the Umrar River, a little above the village Khalesar. It is, in all, about 3 feet 6 inches thick, being made up of thin layers of shale of different degrees of consistency and different shades of colour some of them being indurated, others earthy, some black and others bluish. Amid them is one band or layer of some 6 or 7 inches in thickness of the substance resembling coal, evidently in greater part of vegetable origin and what we have seen to be combustible "

The poor opinion which they formed was probably due to the very dull appearance of coal at the outcrop. However, this is an instance in point showing how dangerous it is to hazard an opinion of the quality of coal and the thickness of coal-seams from surface observations alone and shows the necessity of supplementing such information by careful analysis and by trial borings. Mr. Hughes admits of having committed a similar error when he first examined the Johilla coal-field, and had stated in Vol. XIV of the records, Geological Survey of India, 1881, that the signs were not promising, but he was careful enough not to condemn it. He stated: " I do not condemn it because experience has taught me that many seams (as in the Wardha and Mohpani fields) with thin outcrops may thicken rapidly and furnish a good deal of coal. I can say, however, that the signs are not promising." Subsequent investigations and trial-borings proved conclusively that the seams of coal which were thin at the outcrop and contained poor quality coal thickened in depth and that the quality also improved. From experience attained during the course of surveying operations in many coal-fields he sounded a warning note

to geologists working in a new and unexplored field and advised them to refrain from expressing unequivocal condemnation from surface indications alone. It is worth while quoting his remarks in his own words. He says: "These explorations are another illustration of the expediency of supplementing our geological researches by boring operations, for, like those who preceded me, I formed a poor opinion of the seam from the evidence at the outcrop. The boring and quarrying have proved that something more practical than hammer-tapping is required to frame a correct estimate of the value of a seam." His remarks are indeed very true.

Continuation of the historical part.

After the observations of Messrs. Grant and Hyde nothing had been done for about 20 years in the way of further exploring the Umaria field. The only point of interest was the detection of Talchir rocks, near Lora, about 7 miles to the north of Umaria, by Mr. H. B. Medlicott while he was making a traverse of the rocks between Hazaribagh and Jubblepore. A regular survey of this area was instituted in 1879. In 1880, Mr. Hughes received some samples of Umaria coal which he handed over to Mr. Mallet, who was then Curator of the Geological Museum at Calcutta. The average of Mr. Mallet's determination was as follows:- -

Moisture	11·3
Volatile matter	29·4
Fixed carbon	45·8
Ash	13·5
	100·0

The results of analyses were sufficiently encouraging to warrant a careful examination of the field. The palæobotanical evidence obtained by Lala Hira Lal confirmed

Mr. Hughes' view that the rocks belonged to the lower Gondwana age. The following plant fossils had been discovered :—

Glossopteris communis.
Gangamopteris cyclopteroides.
Noggerathiopsis hislopi.

Mr. Hughes thereupon informed the Rewa administration that true coal-measures occurred near Umaria and Khalesar and suggested that it was expedient to put down borings to explore the field properly. Captain Barr gave a cordial response to this suggestion and Mr Hughes was asked to direct the operations. The first series of borings were put down by Mr. T. G Stewart. Mr. Hughes was also assisted by Mr. Thomas Forster, M.E. and by Messrs Hallett and Munch; all three, were mining engineers. In all, 15 bore-holes had been put down and the indications given by them were quite satisfactory. These were :—

(1) Abundant coal.
(2) Easy accessibility of coal seams from the surface
(3) Low dip of the seams.

Pit No. 1.

On the 11th March, 1883, a pit 10 feet in diameter was commenced. This plan was preferred to that of driving an incline from the top. There being a demand for coal, inclines had to be driven at a later date while the work of sinking the pit was in progress. The site for this pit was selected near bore-hole No. 8 The thickness of the different beds and their sequence as indicated by bore-holes Nos. 7, 8 and 9 was as follows :—

	No 7	No. 8.	No. 9
Sandstones	135′ 0″	93′ 0″	69′ 0″
Coal	13′ 0″	10′ 0″	10′ 0″
Intermediate beds	25′ 0″	8′ 0″	7′ 0″
Coal	11′ 0″	7′ 0″	6′ 0″

The completion of the shaft which was to be about 108 feet deep took about 14 months. There was not much influx of water as long as the sinking operations were confined to the sandstones, but as soon as the coal was reached the water literally poured in and it was found very difficult to cope with it. Though the water was baled day and night without intermission, it kept rising up and further sinking had to be abandoned, at least, temporarily.

Shaft No. 2.

Side by side with the sinking of this pit near No. 8 bore-hole the sinking of a second shaft had been commenced, in December 1883, near bore-hole No. 9. Although water trouble was dreaded, this part of the coal-field proved unusually dry and the shaft was completed without much difficulty. In this shaft seven feet of good coal free from stone bands were passed through. The analysis of an average sample gave the following result :—

Water	5·46
Volatile matter	25·17
Fixed carbon	66·71
Ash	8·12
	100·00

The coal which was analysed by Mr. Mallet in 1880 was found to contain only 45·8 per cent of fixed carbon. The coal from the second shaft was therefore markedly superior to the samples of coal taken a few inches below the outcrop in the sides of the Umrar.

Trial runs.

To prove the quality of the coal under working conditions a few trial runs had been arranged on the East Indian and Great Indian Peninsula Railways by Mr. Thomas Forster, the results of which were very satisfactory. To enable one to

judge of the quality of coal obtained from the outcrop galleries near the Umrar river a few figures in connection with one of the trial runs are given below.

In his description of the trial run on the G.I.P. Ry between Jabalpur and Sohagpur, Hughes makes it quite clear that the coal was not specially selected and that only the clinker band had been removed. This particular trial run was made on the 12th May, 1884, with a train of an average gross weight of 410 tons, excluding the engine and tender. The distance between Jabalpur and Sohagpur Station is 122 miles. The run was completed in 10 hours and 40 minutes, and the total consumption of coal was 2 tons, 6 cwts., 1 qr and 21 lbs. The evaporation was 5 4 lbs. to 1 lb of coal. It was found that the coal steamed rapidly and that even when going uphill with the full load, steam continued to blow off from the safety valve. The number of pounds of coal consumed per train-mile was found to be 42·63. The comparative figures for the Karharbari, Raniganj and Mohpani coals given by Mr. Hughes in Memoir XXXI are as follows :—

Karharbari	Umaria	Raniganj	Mohpani.
39·36 lbs.	42·63 lbs.	51·00 lbs.	55·00 lbs.

The report of the Locomotive Superintendent of the Great Indian Peninsula Railway was also very favourable. His remarks were that the coal was of very good quality and that it steamed much better than either the Warora or the Mohpani coals and was not very much inferior to that from the Giridih Collieries in Bengal. It was also stated by him that the coal had very little clinker, threw off very few sparks, and made little smoke. The only adverse criticism was that the coal had a large amount of ash. The good quality of the Umaria coal was thus proved not only by chemical analyses but by practical tests.

Regarding the total thickness of the coal it may be stated that bore-hole No *7a*, the site of which had been selected by Mr. Hughes between the villages Umaria and Lalpur, on the right bank of the Umrar, proved a maximum thickness of 24 feet of coal at a depth of 184 feet from the surface in two seams measuring respectively 13 and 11 feet. The dip of the measures was found to be very low (about 4° in the inclines); this was a great natural advantage. It was found to run in a north-easterly direction. The outcrop exploration also proved that the roof which consisted of carbonaceous shale was tough and quite sound and except near the entrance to the inclines no timber had been required to support it. This was another favourable point which enhanced the value of the coal seams considerably.

Before closing this chapter on the early history of the Umaria Colliery the writer thinks it worth while to give the analyses of the different bands of the seam which was found outcropping in the quarry near Khalesar during the preliminary explorations. The figures given below which have been taken from Vol. XXI, part 3 of the *Memoirs of the Geological Survey of India* will be found useful for comparison with the results of analyses of coal obtained at the present day. The analyses of a series of samples from the different bands of coal, as carried out in the Laboratory of the Geological Survey of India had given the following results:—

	Exclusive of Moisture.			Moisture.
	Volatile matter.	Fixed carbon	Ash	
A	25·1	55·6	19 3	5·8
C	31 1	55 6	13 3	3·6
D	20·1	58·7	21·2	2 6
E	35·6	56·9	7·5	3 4
F	25·0	36·4	38·3	2 2
H	26 4	60 9	12 7	2·4
,, ...	26·7	59 2	14·1	2·4
,, ...	30·0	53·6	16 4	2·6
,, ...	28 4	60·7	10 9	2 8

Bands C and E consisted of bright soft coal. The band D was found to clinker readily. The band F which contained a large percentage of ash was found to yield on distillation about 15 per cent of oils and tarry matter. According to Mr. Hughes the bottom portion of the seam was the best; it was good steam-coal. Another noteworthy feature of coal from this particular band was that it resisted weathering admirably. There was, however, one objectionable element in this coal. This was sulphur, which was present in the coal in the form of iron pyrites. Mr. Hughes was rather apprehensive of this impurity and he had clearly stated in his *Memoir* that though there was not enough of this material to cause anxiety in stacked coal he enjoined those in authority to exercise care to keep the workings perfectly clear of dust. He wrote " . . . . otherwise the misfortune that overtook the Warora Colliery will probably be repeated at Umaria, and loss both of life and money may be the result."

On the 21st January, 1885, the destinies of the Umaria Colliery were placed in the hands of the Government of India. Up to that time the Umaria Colliery was under

the control of the Rewa Administration. According to Mr Hughes the Government of India had decided to work the Umaria Colliery during the minority of Maharaja Venkat Raman Singh Bahadur and to pay a handsome royalty of eight annas a ton on the raisings. In 1900, the Government of India handed the colliery over to the Rewa Durbar. Thus it will be seen that the detail survey of the southern Rewa coal-fields took about two years from the time of its inception in 1879-80 and that the preliminary explorations lasted for about 3 years, the first boring having been commenced on the 22nd January, 1882. The quantity of coal raised in 1883 was 1,290 tons while 20 years after (in 1903), 191,686 tons of coal were mined. This speaks well of the activity of the management and of the importance which the Umaria Colliery had acquired in so short a time.

II. Physical Description.

The coal-bearing area which lies to the south of Lat. 23° 40′ consists of four distinct coal-fields to which Mr. Hughes gave the names Umaria, Korar, Johilla, and Sohagpur. All these four coal-fields are situated within Rewa territory. For the sake of convenience the very same names are used in this bulletin It seems very likely that the largest coal-field in this part which Mr. Hughes designated as the Sohagpur coal-field will shortly be known by other distinctive names, such as Burhar coal-field, Anuppur coal-field, Rampur coal-field, etc. Mr. Hughes had used in his *Memoir* the comprehensive title of Rewa Gondwana Basin to denote the area comprised by the four above-named coal-fields as also by the coal-fields of Jhilmilli and Korea Zemindaries, on the eastern border of the Sohagpur Tehsil.

The Umaria, Korar, Johilla, and Sohagpur coal-fields occupy a stretch of country about 90 miles long and 40 miles broad which lies between Lat. 23° 10′ and 23° 38′, Long. 80° 50′ and 82° 15′. This area does not consist entirely of Barakar or the coal-bearing formations as the different coal-fields are separated by rocks of a later period, known as the supra-Barakars. To the south of these coal-fields extends the great trappean plateau; towards the east there are large deposits of Talchir and Barakar rocks with a few inliers of gneiss; towards the north there are extensive deposits of supra-Barakar rocks, while towards the west there are gneissic and metamorphic rocks; also, volcanic rocks (traps) and rocks of lower Vindhyan age.

The country in which the coal-fields are situated is,

on the whole, very hilly, though there are level stretches of land extending for miles, specially in the Sohagpur coal-field. The general height of the plain near Umaria is about 1,450 feet above the sea-level. There is, thence, a gentle rise towards the east. The maximum height of the plain in the eastern part of the Sohagpur Tehsil is 1,936 feet above the sea-level at Jogi (Lat. 23° 15′ : Long. 82° 7′). There are a number of detached peaks in the Sohagpur coal-field which are at a considerable elevation, for instance those of Dhanras, Bilai, Londi, and Mahora which attain altitudes of 2,006, 2,114, 2,214, and 3,368 feet respectively. The famous hill fortress of Bandogarh which is situated at a distance of about 20 miles to the north-east of Umaria is 2,662 feet high. In the trappean plateau there are a number of peaks to the south of the Sohagpur coal-field which attain a height of more than 3,500 feet above sea level. These are Barjana, Singingar, Badhargar and Bakmangurh which are 3,510, 3,679, 3,860, and 3,696 feet, respectively. These form the eastern part of the Maikala range. The sacred shrines of Amarkantak are situated on the easternmost extremity of this range (Lat. 22° 40′ : Long. 81° 86′) not far from Son-Munda, the source of the river Son.

The shape of the hills varies to a certain extent according to the rocks of which they are made. Some of the sandstone hills of the supra-Barakar formations are flat-topped with precipitous sides for some distance down and have an accumulation of debris at their base. Bandogarh hill is a striking instance of the characteristic form produced as the result of weathering of the supra-Barakar sandstone. The trap hills, also, have a scarped facing but due to irregular weathering the scarped sides are not quite so precipitous.

Rivers and their tributaries

The rivers Son, Narbada, and Johilla, all, take their rise at Amarkantak in the Maikala range. The particular spot where the Son originates is known as Son-Bhadra or Son-Munda. A short distance from its source it falls in a cascade over the edge of the Amarkantak plateau and thence flows through the Bilaspur District till it again enters Rewa territory at 23° 6′ N., and 81° 59′ E. The Narbada takes a westerly course and does not re-appear in Rewa territory The Johilla flows for about 60 miles in the hilly country mostly consisting of trap and lameta formations from which it emerges near Pali and thence flows in a north-easterly direction among supra-Barakar rocks till it joins the river Son near Obra. The Mahanadi River which is also a tributary of the Son forms the boundary line between Jubblepore District and the western part of Bandogarh Tehsil in Rewa State and flows among Bijawar and supra-Barakar rocks. Other tributaries of the Son are Murna, Sarpa, Kunuk, Kaser, Bageha, Tipan, and Kewai. Three large rivers, the Banas, Gopat, and Rer meet the Son outside the ground which is described here

Vegetation.

There are many picturesque spots in the country which lies between Chandia and Venkatnagar. The scenery is, in many places, exquisitely charming. This is due to the luxuriant vegetation, the hilly nature of the country, and to the small and large streams which flow through it. In the plateau to the south of Umaria, Pali, and Sohagpur, bamboos grow plentifully ; also in the Bandogarh Tehsil at Tala and Kaseru, and in the adjoining parts.

Climate

The climate is very pleasant. The thick jungle-clad nature of the country modifies the heat of the summer. After the rains

the country looks delightful with its thick jungle and heavy foliage The climate is very bracing, particularly so during the winter. The average rain-fall at Sohagpur is about 48 inches. In 1915–16 the rain-fall recorded there was 62 inches The average rain-fall at Umaria is about 45 inches. In 1915–16 the amount of rain-fall was 52·97 inches. The average rain-fall at Bandogarh is about the same as that at Umaria In 1914-15 the rain-fall there was 70 inches.

III. Umaria Coal-field.

General Description.

This coal-field derives its name from the village Umaria (23° 31′ : 80° 53′) which is situated on the left bank of the river Umrar, a tributary of the Mahanadi. Umaria occupies a central position in the coal-field, the greatest length being four miles in a N.W. to S.E. direction, the width measuring about 1½ square miles. The distance between Umaria and Katni is 37 miles. The Katni Bilaspur branch line of the B.N. Railway which runs through the central part of this coal-field has given considerable impetus to coal mining at this place.

The total area of this coal-field is about 6 square miles.

Rocks.

To the west of the field there is an inlier of metamorphic rocks which consist of gneisses, mica-schists, hornblendic rocks, and crystalline limestones. The greatest length of this inlier is 26 miles in a N.E. to S.W. direction. To the south and south-west of the coal-field there is an exposure of Talchir rocks, the easterly limit of these rocks being at Marohi and the westerly, near Pounia. In a north-westerly direction the Talchirs and Barakars extend close to the Narsara stream. The parts to the north and north-east of Umaria coal-field consist of supra-Barakar sandstones. To the east there are a few outliers of trap. These trap outliers are the remnants of the basic rocks which must have once covered all the older formations and which still cover hundreds of square miles to the south of Umaria. The trap rocks are fringed by the Lametas. These consist of calcareous sandstones and gritty limestones. Occasionally beds of good crystalline limestone are found in the Lametas.

Umaria is at an altitude of 1,490 feet above sea-level.

Physical Description.

The area comprised within the coal-field is more or less level but the part lying to the south-west and south which consists of metamorphic rocks is hilly, the highest point having an altitude of 1,788 feet above sea level while the part to the south is very much more hilly. For instance at a distance of about five miles to the south of Umaria there is a hill known as Dandia the height of which is 2,751 feet above sea level. Bandogarh Hill, which is famous for its fortress, is at a distance of about 16 miles to the north-east of Umaria. It is clearly visible from Umaria owing to its great height above the surrounding plain. All these hills and hilly tracts give a very picturesque aspect to Umaria and its neighbourhood. The abundance of trees and coppice adds considerably to the charm of this place. The climate is very healthy.

Rock sections.

The Barakars consist mostly of felspathic siliceous sandstones, occasionally micaceous, sometimes brownish and reddish due to the presence of iron oxide and sometimes of a faint pink colour. The majority of Barakar sandstones are of a greyish white colour. There is no continuous section affording clear evidence of the succession of the different beds. The following is, however, worth notice. Midway between Koilari and Marohi there is a small stream which flows for about ¾ mile among the Talchir rocks and then in the Barakars for a few hundred yards till it joins the Umrar River. In this stream and in the Umrar, good sections can be seen in a few places. In the former, a thin seam of coal about a foot in thickness is exposed not far from the temple which stands on its left bank. The dip of this bed is N.N.E. Near the junction of this stream with

FIG 1
No. 10 Pit. Umaria Colliery, Rewa State.

Photo K. P Sinor

the Umrar certain fossils were found which gave the clue to the true age of the coal bearing formations of Umaria. Dr. Feistmantel of the Geological Survey of India had identified them as follows :—

Glossopteris communis.
Gangamopteris cyclopteroides.
Noggerathiopsis hislopi.

Fossils.

Hughes had discovered many other plant fossils in the Barakars and Talchirs during the course of his survey, and both animal and plant fossils in the Upper Gondwana beds. These were all identified by Dr. Feistmantel. No new fossils had been discovered in the Umaria coal-field since then, till recently when the writer had the good fortune to discover marine Permo-Carboniferous fossils belonging mostly to the genus Productus in the railway cutting close to Narsara Nala about two miles to the N.W. of Umaria Railway Station. These marine fossils occur between the gneisses and metamorphic rocks on one hand, and the Barakars on the other. The marine formation consists of alternating bands of thin Productus beds measuring from 3 to 5 inches in thickness, greenish-grey and yellowish brown shales, and thin bands of limestone and calcareous conglomerate. The beds dip towards the S.S.W. The angle of dip is about 35°. The dip of the Barakar beds is about the same in this part which is suggestive of the fact that there could not have been much lapse of time between the two formations.

Pits, inclines and quarries

There are, in all, 11 pits and 6 inclines at the Umaria Colliery. The following table shows the depths of all the pits and inclines from the surface:—

Southern Area.

			Depth Feet.
Pit No.	1.	Water supply to the camp ..	123
Incline ,,	5	Haulage road from No. II seam (stopped)	143
,, ,,	6.	Travelling road for workmen from No IV seam for ventilation (stopped)	90

Middle Area.

Pit No.	2.	Downcast	131
,, ,,	3.	Downcast	117
,, ,,	4.	Main pumping and downcast ..	236
Incline ,,	1.	Ventilation road to Nos. III and IV seams	120
,, ,,	2.	Ventilation road to Nos. II and III seams	216
,, ,,	3.	Ventilation road to Nos. II and III seams	216

Northern Area.

Pit No.	5.	Upcast and pumping to seams II, III and IV	102
,, ,,	6.	Upcast (fan)	93
,, ,,	7.	Upcast and pumping ..	270
,, ,,	8.	Downcast (drawing coal) ..	254
,, ,,	9.	Sinking suspended	125
,, ,,	10.	Downcast (drawing coal) .	204
,, ,,	11.	Downcast and pumping ..	131
Incline ,,	4.	Ventilation and main travelling road to Nos II, III and IV seams	281

Since many years, coal is being drawn exclusively from Nos. 8 and 10 pits. The workings in No. 8 pit are restricted to No. III seam, and those in No. 10 pit to No. II seam. Coal was quarried on a fairly large scale at the Umaria and Khalesar quarries for many years.

Nos. II, III and IV seams were worked in the Khalesar quarries, and Nos. II and III in the Umaria quarries. The former activity is not manifest now, owing to the contractors having been attracted to Dhanpuri by the unusually thick seam of coal found there near Bageha Nadi (23° 12′: 81° 36′) in the Sohagpur coal-field. At this place which is close to Burhar Railway Station quarrying is conducted on a very large scale, more than 3,000 persons being employed when labour is plentiful.

Coal seams of Umaria coal-field

In the Umaria coal-field six coal-seams have been proved in all Of these, No. III seam is the best It varies in thickness from 8½ feet to 13 feet In the thickest part a band of splint one foot in thickness is met with, at times. In one such band a smooth, water-worn quartzite boulder was found a short time ago The quality of coal varies in different seams and also in different parts of the same seam. The bottom part of No. III seam, for instance, has a higher calorific value than the upper. Similarly the lower part of No. II seam has a higher calorific value and a higher percentage of fixed carbon than the upper. The thickness of the different seams is as follows:—

			Thickness in Feet.
No. I seam	..	..	4′-6″ to 5′-0″.
,, II. ,,	.	..	4′-6″ to 7′-6″
,, III ,,	..	..	8′-6″ to 13′-0″
,, IV. ,,	..	..	3′-0″ to 4′-6″.

Quality of coal.

The following analyses show the quality of coal at present mined. It will be seen therefrom that the bottom part of No. III seam is the best. The next best is that of No. II seam bottom section. The coal from No II seam bottom section is superior to that of No. III top while No. II top

section coal is inferior to that of No. II bottom section The coal in all the seams is non-caking. The colour of ash is pure white. A great point in favour of Umaria coal is its ability to withstand weathering. The white colour of its ash goes in its favour for use in the lime-kilns

No. of Seam.	Mois-ture	Volatile matter.	Fixed carbon	Ash.	Calorific value.
					calories
No. II Top ..	7·05	22·20	41·35	29·40	4,803
" " Bottom	7·27	24·05	48·28	19·50	5,307
No. III Top ..	7·36	25·06	47·89	19·69	5,266
" " Splint..	7·30	22·05	42·85	26·90	4,599
" " Bottom	3·22	22·83	61·05	12·90	6,315

Quantity of available coal.

Regarding the quantity of available coal in the Umaria coal-field two estimates have been made one by Mr. Hughes who estimated in 1885 that there were 55 million tons of coal available within a depth of 500 feet from the surface. The second estimate was made by Mr. R. J. W. Oates in 1902. According to him the total quantity of workable coal was 24 million tons. Mr. Hughes' estimate was based on the knowledge obtained by borings. As stated in the historical notes the maximum thickness of coal passed through in No. 7*a* borehole was 24 feet at a depth of 184 feet from the surface. Taking an average thickness of 20 feet the total quantity of coal in four square miles would be 80 million tons of which 55 million tons were considered to be available by Hughes within a depth of 500 feet from the surface. The estimate of the total quantity of workable coal made by Mr. Oates was also based on knowledge gained by shafts and borings

FIG. 2.

No 8 Pit Umaria Colliery, Rewa State.

Photo. *K. P. Sinor.*

but unfortunately data regarding these are not available. It is very likely that his estimate of 24 million tons was for workable coal within a depth of 300 feet from the surface. Since 1902 the Umaria Colliery has produced nearly $3\frac{1}{2}$ million tons of coal so that according to the very modest estimate made by Oates the quantity of workable coal now available is at least 20 million tons. It is however extremely likely that some of the Umaria coal seams extend right up to the edge of the Korar-Kotalwar field. In such a case the total quantity of available coal would be considerably greater than in the estimates given above. Of course the covering of supra-Barakar rocks would be considerable at Kua and Maihmar and it is merely a matter of guess work as to how much of this concealed coal would be workable. However, as long as there is enough coal available within a reasonable depth from the surface to the east of Lalpur and Umaria the coal in the northern area is not likely to be utilized as this area is faulted and the dip also is higher there than in the other parts.

The following table shows the annual output and cost per ton of coal from 1884 to 1920:—

Output of Rewa State Collieries, Umaria, C.I.

Year.	Output of Coal	Cost per ton.		
	Tons	Rs.	A.	P.
1884-85	2,187	3	15	0
1885-86	9,455	10	0	10
1886-87	7,724	10	8	1
1887-88	25,547	1	2	3
1888-89	50,067	4	6	2
1889-90	57,274	3	9	9
1890-91	75,812	3	3	9

Year.	Output of Coal.	Cost per ton.		
	Tons	Rs.	A.	P.
1891-92	69,761	3	12	6
1892-93	94,847	3	9	2
1893-94	104,568	3	3	10
1894-95	126,706	3	2	2
1895-96	121,198	3	4	3
1896-97	116,571	3	6	11
1897-98	119,346	3	2	10
1898-99	153,541	2	14	11
1899-00	155,865	2	11	7
1900-01	170,543	2	10	6
1901-02	168,612	2	10	6
1902-03	176,700	2	8	5
1903-04	191,686	2	7	11
1904-05	175,740	2	7	8
1905-06	164,891	2	5	0
1906-07	167,619	2	7	3
1907-08	187,197	2	8	7
1908-09	132,008	2	9	8
1909-10	120,309	2	8	5
1910-11	137,562	2	5	3
1911-12	148,785	2	9	7
1912-13	149,463	2	4	9
1913-14	150,078	2	10	3
1914-15	142,088	2	11	8
1915-16	192,628	2	10	8
1916	200,285	2	7	5
1917	198,407	2	9	7
1918	199,975	2	10	5
1919	157,150	3	0	7
1920	158,051	3	6	7

IV. The Korar Coal-field.

Boundaries.

About five miles to the north of Umaria there is another exposure of Barakar rocks whose total area is about 10 square miles. This coal-field has a roughly triangular outline, having Tagatpur as its southern apex and Khaira and Kherwa as the north-eastern and north-western apices respectively. The coal-field had been named Korar coal-field by Mr T. W. H. Hughes, but the name Korar-Kotalwar coal-field is more precise. About half a dozen large streams flow through this coal-field, the principal being the Umrar. The junction of this stream with those flowing from Bareri, Murguri, Korar, and Kotalwar determines the northern boundary of the coal-field. To the north-west of Korar there is an exposure of trap rock, covering about two square miles. Its southern extension which runs between Bardouha and Khaira has an area of about one square mile. To the south-west of this coal-field there is an inlier of Talchir rocks which is continuous with the Talchir rocks exposed at Lagwari and Lora. To the west of Achala and Kherwa and to the east of Tagatpur and Khaira the Barakar formations are overlain by the supra-Barakar sandstone

Rocks.

The Barakar rocks consist, as in other parts, of grey and yellowish felspathic sandstone, beds of carbonaceous shales, and seams of coal. There are, in all, six outcrops of coal and carbonaceous shale. These are near Achala, Korar, Khaira, Jwala Mukhi, Barbaspur, and Dudraumri. The first boring for coal was undertaken in this coal-field in 1884 near a place known as Achala. Although this boring

reached a depth of about 181 feet from the surface it did not reveal any good seam of coal. At three different horizons coal was struck but it was mixed with shale, and the total thickness of the coal and shale combined was only about 8 feet Thus, neither the quality nor the quantity showed any improvement in depth.

Rock sequence. The following rocks were passed through :—

	Ft.	In.
1. Sandstone, brown, grey, and yellow	58	2
2. Carbonaceous shale and sandstone ..	2	0
3. Carbonaceous shale and coal .	4	0
4. Sandstone with pyrites	10	0
5. Shale with coal	2	0
6. Blue shale	1	0
7. Sandstones	52	0
8. Grey shale with coal	2	0
9. Sandstone, etc.	50	0
Total	181	0

Mr. Hughes then selected another site for boring; this was between Kotalwar and Korar at a place known as Jwala Mukhi. In this case the results obtained by boring showed a considerable advance on the indications given by the surface outcrop. Three seams of coal 8′, 4′, and 4′ in thickness were met with at depths of 12′, 23′ and 29′ respectively. The total depth obtained by the borings was 122 feet. A second boring struck a seam of coal 7 feet thick at a depth of 48 feet from the surface; its total depth was 63 feet.

The thickness and succession of the different beds disclosed by the section at the outcrop near Jwala Mukhi is as follows :—

	Ft.	In.
Shale	4	0
Coal	2	0
Shale parting	0	6
Coal	1	6

The results of the two borings laid down near Jwala Mukhi were as follows :—

No. 1.

		Ft.	In.
1.	Sandstone	6	0
2	Sand with gravel	3	0
3	Sandstone	3	0
4	Coal	8	0
5	Shale, carbonaceous	3	0
6	Coal	4	0
7.	Shale Carbonaceous	2	0
8	Coal	4	0
9.	Shale	8	0
10.	Sandstone	62	0
11	Shale	8	0
12.	Sandstone	11	8
		122	0

No. 2.

		Ft.	In.
1	Brown surface soil	3	0
2.	Sandstone	42	0
3	Sandstone shaly	3	0
4	Coal	7	0
5	Shale carbonaceous	6	0
6.	Sandstone grey	2	0
		63	0

The dip of the coal seams varies from 8° to 10° in a N.N.W. direction. The analysis of a sample of weathered coal conducted in the Geological Survey Laboratory gave the following results :—

Moisture	5 04
Volatile matter	12·56
Fixed carbon	65·48
Ash	16·92

The amount of fixed carbon is high which speaks well of the quality of the coal. The percentage of ash is rather high but it is quite likely that coal found in depth would show an improvement on the weathered coal. There is no doubt that the coal extends to the north and north-west of Kotalwar in the direction of Khaira and Korar. To prove whether the coal extends in a westerly direction it would be worth while to undertake a boring about a mile and a half to the north-east of Achala. Another site which could be recommended for a boring is one about a quarter of a mile to the south of Barbaspur.

Future of the Korar coal-field.

So long as there is enough workable coal in the Umaria coal-field it is obvious that the Korar coal-field will remain undeveloped. The distance between Umaria railway-station and Jwala Mukhi where a boring revealed three seams of coal 8′, 4′ and 4′ in thickness is eight miles. This detracts from the value of the Korar field. Again there are large undeveloped areas close to the railway line in Johilla and Sohagpur coal-fields. The construction of a siding seven to ten miles long would not appeal to any one unless there were great counterbalancing advantages. These are not many. If a boring south of Tali[1] proved the presence of coal, a siding near Lora[2] would serve to open up the coal-field. Such a siding would have the advantage of being six or seven miles nearer to Katni than Umaria.

Estimate of quantity not possible.

Regarding the total quantity of workable coal in the Korar coal-field it is too early yet to arrive at any conclusion. Although the boundaries of the Barakar formations have been approximately fixed, our knowledge of

[1] 23° 38′: 80° 53′. [2] 23° 35′: 80° 50′.

the thickness and disposition of the coal seams in different parts of this coal-field is very meagre, excepting the part which lies between Kotalwar and Korar. As the coal measures dip to the north and north-west it is extremely likely that the coal seams extend underground below the formation which has been marked supra-Barakar. It is also likely that they extend southward in the direction of Bareri. Until further borings are laid down it would be difficult and even undesirable to make a close estimate of the available quantity of fuel in this coal-field.

V. The Johilla Coal-field.

About 18 miles to the south-east of Umaria railway-station on the Katni Bilaspur branch line of the B.N. Ry. there is a station known as Birsingpur. The Johilla coal-field is quite close to, and easily accessible from, this station. The Barakar formations are here divided into two distinct parts by Talchir and gneissic rocks. The southern exposure has an area of about 3½ square miles while the northern exposure has an area of about 11 miles. In the southern area there are no outcrops of any importance. The northern part consists of a bed of coal about 12 feet thick exposed in the Ganjra Nala, a tributary of the Johilla river, near their confluence. The Johilla coal-field takes its name from the Johilla valley. As mentioned in the chapter on physical description, the Johilla river takes its rise in the high trappean plateau of the Maikala range near Amarkantak where the sacred shrines are situated. For more than sixty miles it meanders its way on the trappean plateau gradually passing to lower levels by a series of descents in the shape of waterfalls and cascades. It enters the coal-field near the village Lakhanpura and winds its way over the Barakar formations for 2½ miles. Near Maugthar, it flows through the Talchirs for about half a mile and then enters the metamorphic rocks. For 2 miles it flows through these rocks and then again passes over Talchirs. Not far from Bara Chada it enters the Barakar rocks through which it flows for about a mile and then enters the broad expanse of the supra-Barakar, over which it flows for nearly 30 miles before it joins the river Son.

Southern area

The southern part of the coal-field is not very important from an economic point of view. In the first place, its shortest distance from Birsingpur Station is 4 miles. Secondly, there are no outcrops of any importance in this part of the field. For the present, therefore, it does not seem as if the southern part of the Johilla coal-field will be developed. There are two outcrops, one near Amuari where the road from that village to Lakhanpura crosses the Johilla and another to the south of Mangthar on the right bank of Johilla At the former locality there is a band of coal and carbonaceous shale about a foot in thickness; near Mangthar the thickness of the bed of coal and coaly shale is about 2 feet. The measures dip towards the S.S.E. It is, therefore, quite reasonable to suppose that the Barakars extend underneath the Lametas of Isunpura and Taktai.

Northern area.

The Barakars of the north area of the Johilla Valley coal-field occupy an area of about 11 square miles. They form a roughly crescent shaped belt having a width varying from about a quarter of a mile on its eastern side to about three miles on its western extremity This belt runs more or less parallel to the railway line for six miles from Bara Daigaon to its eastern extremity near Kumurdu. The Ganjra Nala runs for about 3½ miles in the eastern part of the coal-field before it meets the Johilla. In the western part of the coal-field two streams the Bichua and Dhobghata run for about four miles from the south to the north-east and meet the Johilla close to Bara Daigaon. Two other streams the Marjada and Umarha also flow from south to north and meet the Johilla to the south of Bara Daigaon.

Early notice of this coal-field.

The first person to notice this coal-field and record it was Dr. Spilsbury who mentioned this fact in the Journal of the Asiatic Society of Bengal in 1840. He was also the first person to mention the discovery of coal near Khalesar and Umaria. During the time of Raja Ajit Singh the Marathas had taken possession of Singrauli, and the Sohagpur Taluk including Amarkantak and adjoining parts. These had then passed into British possession. At the time of Dr. Spilsbury's visit they belonged to the British Government. For valuable services rendered by Raja Raghuraj Singh during the Mutiny of 1857 the Sohagpur Taluk and Amarkantak District were granted to him and with these the coal land near Johilla also passed to the Rewa State. The next mention of Johilla coal-field was made by Major Wroughton in 1854. Mr. J. G. Medlicott gave in 1860, a short account of coal near the village of Maliagura in the Johilla valley in Vol. II, Part 2, of the Memoirs of the Geological Survey of India. In 1881 Mr. T. W. H. Hughes surveyed this coal-field and in 1882 three borings were put down under his directions. Our present knowledge of this coal-field is mainly based on his valuable observations and the exploratory work that was conducted under his able supervision.

Rock formations of the Johilla Valley.

The rocks exposed in the Johilla Valley are the following:—

1. Alluvium.
2. Trap.
3. Lameta.
4. Supra-Barakar.
5. Barakar.
6. Old crystalline rocks, gneiss, and schists.

Alluvium. Alluvium covers the different formations here and there. The soil is on the whole black which suggests its derivation from the trap rocks. The supra-Barakar rocks are covered in many places by a thin bed consisting of earthy matter in which pebbles of trap abound. This accounts for the presence of black soil in places where the underlying rocks are supra-Barakar sandstones. This formation was evidently covered by the trappean rocks in remote ages. By gradual denudation and weathering much of it has disappeared but, here and there, small and large trap outliers may be seen resting upon the supra-Barakars and Barakars both.

Trap. The trap rock of these parts is a highly basic basalt consisting essentially of augite, plagioclase felspar, iron oxide, and basic glass. Its specific gravity is 3–3·1. Not far from Ganjara Nala there is a plot in one of the bends of the Johilla River, where pebbles and boulders of trap, smoothed and rounded by the action of water, occur plentifully. These were at one time employed by the Katni Cement and Industrial Company in their tube-mills as they are hard and resist wear and tear fairly well.

Lameta rocks. The Lameta rocks which are exposed in the Johilla Valley mostly occur as a fringe to the trap rocks. About a mile to the south of Maliagura and about one and a half mile to the east of Ponri there is an outlier of Lameta rocks overlying gneissic rocks. This formation consists mostly of gritty limestone but patches of pure crystalline limestone also occur in it. In some parts, the rock resembles a calcareous grit more than a limestone, while in others the rock consists entirely of a greyish finely crystalline limestone.

The supra-Barakars extend for many miles to the

north of the outcrop of coal measures. As the latter dip towards the north it is quite likely that coal would be met with, below the supra-Barakar sandstones, at no great depth, on both sides of the railway line between Malhadu and Sahtara.

Supra-Barakar.

Barakars.

The Barakars of the Johilla Valley do not differ from rocks of the same age occurring at Umaria and Korar. They consist mostly of yellowish grey felspathic siliceous sandstones, shaly sandstones, carbonaceous shales, and seams of coal. Of these, the massive sandstone occurs largely. Different species of Glossopteris and Gangamopteris were found by Mr. Hughes and his party during the course of the survey and exploration of this area. Other plant fossils found were: Vertebraria indica, Noggerathiopsis hislopi and Samaropsis, comp. parvula. Dr. Feistmantel who identified these fossils stated that the fossils found in the coal measures of the Johilla Valley corresponded to the assemblage of fossils found in the second and third seams of the Karharbari coal-field. On this ground alone Mr. Hughes did not think it fit to separate the above rocks from the Barakars as their lithological characters were not such as to justify a division of the coal-bearing rocks. The position remains practically the same even at the present day, as no special characteristics have been noted in the coal-bearing rocks of this area nor have any distinctive zonal fossils been discovered in them to warrant the allocation of some of the beds to the Karharbari and others to the Barakar stage.

The Talchirs.

The Talchir rocks occupy a belt about six miles long and one and a half mile wide between the villages of Kudri and Kumurdu. There is a small band to the north of Mangthar but

the exposures there are not so good as those in the northern part between Ponri and Bara Chada. Some very good sections of these rocks could be seen in the reach of the Johilla River near Bara Chada. The bottom bed consists of a compact greyish highly calcareous sandstone. This rock may with equal propriety be called a siliceous limestone as it contains a large amount of calcite This bed is succeeded by a thick bed of greyish green silt containing fragments of quartzite, granite, and schist This is covered by yellowish and greenish silts, compact calcareous sandstones, and soft felspathic sandstones and silts. As stated above, the best exposures are in the banks of the Johilla River. Towards the east these rocks are covered by alluvium a short distance from the right bank of the river but towards the west they can be located in many places in the small and large nullas

Gneisses and metamorphic rocks.

The metamorphic inlier of the Johilla Valley covers an area of about 8 square miles. Towards the north this exposure is covered almost wholly by Talchirs and partly by alluvium. Towards the south-west it is fringed by Lameta rocks, while to the south-east and east it is concealed by Talchir rocks, supra-Barakars, and alluvium.

Results of Boring Operations on the Johilla Coal-Field.

The largest coal outcrop in the Johilla field is one near the confluence of the Ganjra Nala and the Johilla River. The thickness of coal at this outcrop is about 12 feet. In 1882, a boring had been put down to the north-west of this outcrop, a short distance from the left bank of the Johilla River. The results of the boring showed an improvement in the thickness of the seam. The measure-

ments obtained at the surface, and the results given by the Johilla Valley bore-hole No. 2 were as follows:—

Outcrop Measurements.

	Ft.	In.
Sandstone.		
Coal and coaly shale ..	12	0
Grey micaceous sandstone	5	0
Coal and coaly shale ..	6	0
Argillaceous shale .	2	0

Johilla Valley Bore-hole No. 2.

	Ft.	In.
Dark surface soil .	1	0
Sandstones	5	0
Coal . ..	17	0
Sandstone	1	0
Carbonaceous shale ..	6	0
Carbonaceous shale and sandstone	12	0
Coal	6	0

Bore-hole No. 1 near Marjada outcrop.

The seam which outcrops in the Ganjra Nala can be traced to the west in two different places, one, in a small feeder a few hundred yards to the west of the site selected for bore-hole No. 2 and the other, near the junction of the Umaria and Marjada streams. Not far from this junction another boring had been put down which disclosed the following section:—

Bore-hole No. 1 Johilla Valley.

	Ft.	In.
1. Yellow clay	1	0
2. Sandstone and shale	15	0
3. Carbonaceous clay and shale	11	0
4. Sandstone	7	0
5. Coal	17	0
6. Carbonaceous and grey shaly sandstone ..	2	0
7. Coal	3	0
8. Carbonaceous shale and sandstone	5	0
9. Coal	8	0
Total ..	69 feet	

The dip of the measures was found to be 6° in a nearly due north direction.

FIG 3

Photograph showing outcrop of Coal near the confluence of the Ganjra Nala and the Johilla River. A tunnel was driven in this outcrop forty years ago, the entrance to which is seen in the figure near the place where the man is standing.

Photo. K. P. Sinor.

Bore-hole No. 3 near Dhobghata.

A third boring was started about a mile to the south-west of Bara Daigaon in the Dhobghata Nala where there is a minor outcrop of coal. This boring passed through about 150 feet of sandstones. As no coal was met with, the boring had to be stopped.

The following analyses of a few samples of coal from Marjada Nala and of samples of Umaria coal selected by Hughes are useful as they show the comparative merits of the two kinds

	Johilla			*Umaria.*		
	1	2	3	1	2	3
Volatile matter ..	32 31	35 60	36 64	26 70	26 40	28 40
Fixed carbon ..	54 58	52 77	55 93	59·20	60 90	60 70
Ash	13 11	11 63	7 43	14 10	12 70	10 90

About 20 tons of coal from the Marjada Nala outcrop had been sent to the G I.P. Railway for a trial run in Mr. Hughes' time. The results of the trial were quite satisfactory and the Johilla coal was reported to be slightly superior to the Umaria coal. This does not quite agree with the results of the analyses but it is quite likely that the coal quarried near Marjada Nala was of better quality than the samples selected by Mr. Hughes.

Importance of the Johilla coal-field.

It is nearly 40 years since exploratory work was started on the Johilla and Umaria coal-fields Although the results shown by borings on the Johilla coal-field were quite satisfactory, the proximity of Umaria to Katni went in favour of the Umaria coal-field which was opened out and developed soon after, while the Johilla field has remained dormant all these years However, this coal-field possesses distinct advantages and it is almost certain that it will soon come into prominence as the demand for coal

is increasing every day. Proximity to a railway, good quality of fuel, thick and workable seams of coal close to the surface, plenty of labour, and a good climate are some of the advantages which this coal-field can claim. The distance between the two places where borings Nos. 1 and 2 were put down is one and a half mile. The borings conclusively show the presence of two seams of coal about 17 feet and 8 feet respectively. Even supposing that thin partings of shale occur in the 17 feet seam there is at least 20 feet of coal available from the two seams. Besides, the quality of the coal is fairly good as shown by the analyses, a fact which was supported by the trial run on the G.I.P. Railway. The following shows clearly and convincingly the high opinion which Mr. Hughes had formed regarding this coal-field. "It is fortunate that justice had been done to the Johilla Valley, for, notwithstanding the fact of its coal being 13 to 14 miles further from Katni than Umaria, it will prove either a very formidable rival to that field or a seasonable reserve according to the conditions on which the lease of Rewa mining rights is granted. There appears to be quite 20 feet of coal and although the outcrop of the seam cannot be traced for more than two miles it is almost a certainty that both in the direction of Khodargaon and of Pali shallow sinkings would touch it."

VI. The Sohagpur Coal-field.

Extent of coal-field.

This, the largest coal-field of the Rewa State, has an area of about 1,200 square miles. Hughes included the coal-field of Korea and Jhilmili under the designation of Sohagpur coal-field, but as these two coal-fields lie outside the territorial limits of the Rewa State the writer has thought it best to give the name of the Sohagpur coal-field to the area which lies within Rewa territory only and which stretches through one degree of longitude (81° 15′ to 82° 15′) The total area of the Sohagpur coal-field and the adjoining coal-fields of Jhilmili and Korea is about 1,600 square miles These three fields stretch through about two degrees of longitude from the river Son to the river Rer. In the following notes, only the part lying within Rewa territory is described.

Previous observers

Franklin was the earliest observer who recorded in 1830 the presence of a seam of coal near the junction of the Tipan stream with the Son, 30 miles to the S.E. of Sohagpur. To Hughes belongs the credit of exploring the whole of this coal-field, of demarcating its boundaries, and of recording a number of outcrops of coal. In 1899–1900, G. F. Reader further explored the western part of this coal-field in proximity to the railway line.

Boundaries of the Sohagpur coal-field.

The westernmost exposure of this coal-field is near Ghunghuti Railway Station (Lat. 23° 20′: Long. 81° 13′) which is 12 miles to the west of the Sohagpur village, the headquarters of the Tehsil. From this to the most easterly exposure at the village of Kanai (Lat 23° 22′:

Long. 82° 14′) close to Hasia Nadi there is a distance of 64 miles The maximum width of the coal-field is about 30 miles in a north to south direction. The villages Khaira, Dhanoura, Anuppur and Chokan are situated near the southern boundary of this field. The limit of the Barakar rocks to the south is fixed by Lat. 23° 5′ below which there are no coal-bearing formations in Rewa territory The most northerly point of this coal-field is at a latitude of 23° 34′. Above this latitude there are coal-bearing formations in Rewa State but they belong to a separate coal-field known as the Singrauli coal-field.

Rock formations.

The area covered by this field consists mostly of the ordinary greyish white and yellowish grey felspathic sandstones which form such a characteristic feature of the Barakar rocks. Occasionally ferruginous sandstones are met with, which really belong to the Barakar group, though in appearance they are more like the rocks of the Mahadeva series belonging to the upper group. Care should, therefore, be exercised in fixing the horizon of such rocks. One such exposure is seen in the extreme eastern part of this coal-field near the union of the Jhiria and Kulharia Nala (Lat. 23° 7′: Long. 82° 10′). The dip of the measures is low and there is not any evidence of faulting in this field. In the area occupied by the coal measures there are two or three small outliers of supra-Barakar rocks and an inlier of Talchir rocks. Dykes and intrusions of trap rock occur throughout this coal-field but they are more frequent in the western part to the north and north-east of Sohagpur. The newer rocks, viz. the ferruginous sandstones of the upper group and the Lametas lie unconformably on the Barakars. The southern part of the coal-field is bounded mostly by Talchir rocks from longitude 81° 36′

to longitude 82° 15′. West of Long. 81° 36′ the Barakars are covered mostly by the supra-Barakar sandstones with the exception of a small patch south of Dhamni and Dhanoura which is covered by Lameta rocks

Paucity of outcrops of workable coal seams

After a close survey of this coal-field Hughes came to the conclusion that this field was not very rich in coal and that outcrops of workable seams were by no means plentiful. He estimated the thickness of the main seam of the western area near Burhar and Amlei at more than 5 feet and that of two smaller ones underlying it at from 12 to 30 inches.

Thickness of the main seam more than 25 feet near Dhanpuri.

Subsequent investigation by G. F. Reader in 1899–1900 showed that the thickness of the main seam varied from 15½ feet on the Bageha stream near Dhanpuri and Amlei to about 5 feet on the Son River between the villages of Bakahi and Chaka. Later developments have shown that the Dhanpuri seam attains a thickness of 27 feet in some parts. It may, however, be stated that this thickening appears to be quite local.

Seam '*par excellence*' of the Sohagpur coal-field.

Although the thickness of this seam was under-estimated by Hughes, probably because much of the coal was concealed, it must, in fairness to him, be made clear that he was the first to point out that the seam which is exposed in the Bageha and Narsara streams between the villages of Burhar and Amlei was the seam *par excellence* of the western part of the Sohagpur coal-field. The proximity of the Katni-Bilaspur branch line of the B.N Ry. makes this part very important, at present. The western part of the coal-field, will therefore,

be described first and the description will proceed from west to east.

Part between Ghunghuti and Sohagpur and its northern extension

At the westernmost extremity of the coal-field we find that the railway line actually passes through the Barakar rocks on both sides of Ghunghuti Railway Station. From there the railway line runs eastward over the supra-Barakar formations in a nearly parallel line with the southern boundary of the Barakar rocks for a distance of about 17 miles, again goes over the coal-measures for about 16 miles and then passes over Talchir and metamorphic rocks. It may be stated at the outset that there are no outcrops of any importance in this western part (between Ghunghuti and Sohagpur) except one near Jamua which attains a total thickness of about 7 feet. Thin outcrops of coal and coaly shale occur at Semriha, Kannabahra, and Mahroi to the west of Sohagpur. To the north-east of Sohagpur, between it and the Son River, coal has been noted near Nipania, Kathari, Maiki, Kushai, and Semdih. None of the seams exceed 2′ 6″ in thickness, the dip varying considerably, occasionally being about 8°. The average dip, however, is considerably below this. Going further to the N.E., coal is met with on the other side of the Son near Diapipar, Singaora and Silpari. The thickest of these three seams is that near the union of the Singaora Nala with the Son but even this is, practically, of no importance. Further down the river there is not a single outcrop in the bed of the river for more than eight miles. The next exposure in the bed of the Son is near the village of Gurarn where three bands of coal 5′, 2′ 4″, and 2′ thick are exposed. The coal is, in many places, found under a cover of sandstones and is interstratified with coaly shale.

Nearly five miles to the south of Guraru there is an outcrop in the Murna River between the villages of Bijauri and Udri. The thickness of the seam is about 5 feet but the exposed coal is not of good quality.

Part lying between Long. 81° 30′ and Long 81° 45′ Area near the railway line and to the south of it

Having described that part of the coal-field which lies between Long. 81° 15′ and 81° 30′ we shall now proceed to describe the area near the railway line between longitudes 81° 30′ and 81° 45′ and then treat the southern and northern extensions thereof. Proceeding from west to east we find that the railway line crosses the Sarpa Nadi, Bageha Nadi, Suthna Nala, Bakan Nadi, and Chandas Nadi The most important of all these streams is the Bageha Nadi In a run of about five miles there are four noteworthy outcrops in this river, two to the north of the railway line and two to the south. The coal in all these outcrops is of good quality. To the north-east of Dhanpuri there is an outcrop of coal in the Nargara stream which joins the Bageha close to the railway line and to its south

Bageha outcrops.

The two outcrops to the north of the railway line occur in the bed of the Bageha between the railway bridge about a mile to the west of Jagraha and the union of the Son and Bageha In the first of these the thickness of the seam of coal is 2′ 6″ and that of carbonaceous shale about a foot There is some coal under water the thickness of which is merely a matter of guess. In the second outcrop which occurs in this stream close to the Son River about two feet of coal are exposed. In a trial pit which had been sunk in 1920 close to the outcrop, by a contractor, a seam about five feet thick was revealed. A selected sample

from the first outcrop gave a calorific value of 6,050 while that of the second outcrop gave a calorific value of 5,555.

Pakaria Quarry.

At Pakaria which is situated $1\frac{1}{2}$ miles due north of Burhar Railway Station a quarry had been opened and a large quantity of coal was taken out in 1921 before the commencement of the rainy season. The total thickness of coal mixed with carbonaceous shale is about 8 feet Although the seam is thick it must be stated that the coal weathers very badly due to its laminated structure and thin partings of shale. Selected pieces of bright bituminous coal gave the following analysis :—

	A.	B.	C
	Bright.	Fairly bright.	Bright and dull.
Moisture	1·12	1·25	1·30
Volatile matter ..	28·06	27·51	24·30
Fixed carbon.. ..	58·96	53·34	42·88
Ash	11·86	17·90	31·52

The bright coal is found to coke well. It is unfortunate that thin laminæ of shaly matter and shaly bands are intimately mixed with a large part of the Pakaria coal as their presence makes the coal non-coking, gives it a large percentage of ash, and causes it to crumble away when exposed to heat and rain. The writer examined some coal which was arranged in stacks near the quarries and which had been exposed to heat and rain for eight months, and found that it had deteriorated to a considerable extent.

Semra Trial Pit.

To the north-west of Pakaria at a place known as Semra a trial pit was sunk by a contractor early in 1921. Analysis of a

FIG. 4.
Dhanpuri Quarries, belonging to the Baghelkhund Coal Mining Syndicate, near Burhar Railway Station.

Photo. *K. P. Sinor.*

sample of coal stated to be obtained from this trial pit gave good results. The percentage of fixed carbon is fairly high as will be seen from the following :—

	A	B
Moisture	4·50	3·56
Volatile matter	19·82	17·64
Fixed carbon	60·44	61·67
Ash	15·24	17·13

Samples of this coal gave calorific values ranging from 6,110 to 6,580 which is a clear testimony of the fairly good quality of this coal.

Quarrying operations have not yet started in right earnest at this place as owing to its distance from the railway line steam pumps have not yet been installed. The water which accumulated during the last rainy season is at present being baled out in primitive fashion by small buckets attached to the long arm of a wooden pole pivoted on a forked piece of wood, the short arm being loaded with clay. This is a slow and tedious process. If all the available coal in this quarry is of the same quality as the samples obtained from the trial pit a good future could be predicted for it.

Baghelkhand Syndicate Quarries

South of the railway line in the Burhar-Amlei area the most important outcrop is close to the Bageha stream where the Baghelkhund Syndicate are at present quarrying coal with great vigour. In one particular part, the thickness of the coal seam is stated to be about 27 feet and it is said that there is only about 3 feet of shale in the whole of the exposure. At the time of the writer's visit this particular quarry was under water In other quarries where work had freshly started about 10 feet of coal was exposed. The most extraordinary thing about this very thick seam is that it does not appear to be continuous in a

westerly direction. Not far from the Baghelkhand Syndicate's quarries there is coal land taken on lease by Messrs. Villiers Ltd. Up to the present, no coal is met with at the same level in their plot. Large pits are being sunk on this property at the time of writing these notes, which indicates that trial borings must have revealed a workable thickness of coal in their area also, but details regarding these borings have necessarily been kept secret. In the present state of our knowledge, therefore, no definite statement could be made regarding the continuance or otherwise of the thick seam met with in the Baghelkhund Co.'s quarries This abnormal thickening of the seam is very likely due to overthrust caused by the differential movement of the strata after their consolidation, which piled layer on layer of coal, one above the other. It is quite probable that this movement was caused by the intrusion of the basic igneous rock which is exposed in a narrow strip extending over two miles in an east to west direction to the south of the quarries. The same phenomenon must have occurred near Semra where the seam is about 25 feet thick. There is a boss of intrusive trap rock not far from Semra. In the quarry which was being opened out, the writer had observed a thin vein of igneous rock which had penetrated the Barakar sandstone and had caused slight faulting. It is reasonable to suppose, therefore, that a large mass of intrusive matter may have produced a thrusting movement with the result that the seam was doubled or trebled up at Semra and Dhanpuri. It would be worth while putting trial borings not very far from the trap outlier to see if the coal seam is similarly affected in other parts close to the intrusion. The following sites may be recommended—one, to the north of the railway bridge which crosses the Bagcha ; another, close

to the village of Sabo; a third, about 500 yards to the south of Kelhauri.

Area south of the railway line, between the Sarpa and Bageha stream.

With the exception of the outcrops near Dhanpuri, noted above, there are no outcrops in the whole of the tract lying between the Sarpa and Bageha. To Hughes' mind the probability of coal occurring between Piparia and Khaira close to the Sarpa stream was so strong that he had selected this part for a trial boring and another to the north of it, close to the junction of the Barna and Sarpa streams.

Outcrops in the Son River and Katna and Jamunia streams, between latitudes 23° 10′ and 23° 15′ and longitudes 81° 38′, 81° 43′.

In the Son River there are two outcrops between the villages of Sabo and Bichia. One is about a mile to the east of the union of the Bageha with the Son while the other is close to the mouth of the Jamunia Nala. In the Jamunia there are three outcrops within a run of 3 miles. The third outcrop in the Son is situated between Batoura and Kelhauri In the Katna Nala there is one outcrop to the south of Kureli and another to the south-east of Rampur. The coal in all these outcrops is of fairly good quality, the calorific value ranging from 5,360 to 6,290. In almost all the outcrops the coal is only partially exposed, the remainder being below the surface of the ground. A total thickness of 5 feet of coal may be safely assumed for this area which will come into prominence in the near future owing to its proximity to the railway

Outcrop in the Bakan Nadi.

Two miles to the north-west of Anuppur Railway Station there is an outcrop of coal between Mariaras and Karaibahra in the Bakan Nadi. The thickness of the seam is

3′-3″. It is a matter of regret that the coal is not of good quality. The percentage of fixed carbon is low while the ash content is high. The following is an analysis:—

Volatile matter	28·50
Fixed carbon	44·14
Ash	27·36

It is probable, however, that both the thickness and the quality of coal might improve in depth. The proximity of this area to Anuppur Railway Station is greatly in its favour and it would be worth while sinking trial pits or putting down boreholes between Mariaras and Karaibahra.

Kaser Nadi.

In the Kaser Nadi, which is a tributary of the Son River and which is situated to the north of Katna and Jamunia streams, coal is exposed in many places but none of the outcrops are important except one near Sahipur which attains a thickness of nearly 5 feet at the surface.

Nimhua, Kharla, and Channuri outcrops.

In the lower reaches of the Kaser River there are outcrops near Kharla, Nimhua, and Channuri. The thickness of coal in the Nimhua outcrop is about 2 feet while the other two are partly under water.

Outcrops in the Jamuna tributary near Bargaon and Hatgala.

In the Jamuna Nadi which meets the Kaser about a mile to the south-east of Nimhua there are two outcrops—one near Bargaon, another to the north-east of Belbahra. The first is under water while the thickness of the seam in the other is only about a foot and a half. In a small feeder which joins the Jamuna a mile to the south-east of Hatgala there is another obscure outcrop of coal and carboniferous shale.

Near the village of Birhuli one and a half mile to the

west of the junction of the Kaser and the Son there is a seam of coal measuring 3 feet in thickness which is evidently an extension of the seam near Kharla and Nimhua.

Birhuli Seam.

In the upper part of the Kaser River there are three outcrops between the villages of Bahgar and Bakramar. The lowest of these is $\frac{3}{4}$ of a mile to the east of Bahgar and about a mile to the west of Sahipur. The other two outcrops are due north of the Sahipur outcrop which, as stated above, has a visible thickness of 4 feet, part of the seam being under water. The seam is probably 5 to 6 feet in thickness.

Bahgar, Bakramar and Sahipur outcrops

Although none of the outcrops mentioned above appear to be very promising, it is likely that in the triangular area formed by Birhuli,[1] Bakramar[2] and Bargaon[3] workable coal might be met with, in depth.

Likelihood of workable coal in the Birhuli, Bakramar, Bargaon area

For seven or eight miles to the west of the Kaser Nadi there is not a single exposure of coal in any of the streams or nalas which are tributary to the river Son. Further west, there is an important outcrop of coal near the village of Nandnah close to the junction of the Nagaua stream with the Son and another near the village of Khitauli in an adjoining feeder stream. In the Nandnah stream there are three principal bands of coal having thicknesses 5′, 4′ 6″, and 3′ 6″ respectively, analyses of which are given below :—

Nandnah Seam.

[1] Lat. 23° 21′ : Long. 81° 38′.
[2] Lat. 23° 27′ : Long 81° 46′.
[3] Lat 23° 22′ Long 81° 43′

	No 1 band, 5 feet thick.	No. 2 band. 4 feet 6 inches thick.	No. 3 band; splint coal 3 feet 6 inches thick.
Volatile matter	23·84	26·55	18 28
Fixed carbon	62·50	62·89	48 15
Ash	13·66	10·56	33·57

Outcrop in Kunuk River north of Semdih

Further down the Son River at its junction with the Khairi stream there is an outcrop containing three bands of coal 1′-10″, 3′, and 2′ in thickness, respectively, in descending order. At the junction of the Kunuk with the Son there is another exposure containing a seam 5 feet thick. Both these outcrops are situated to the north of Semdih.

Description of outcrops in the area between Long. 81° 45′ and 82° 0′. Katna Nala outcrop.

We shall now proceed to describe outcrops of coal which lie between longitudes 81° 45′ and 82° 0′. Two outcrops, one near Kureli and another near Rampur in the lower reach of this nala, have already been described Further up the river there is an outcrop containing a seam of inferior coal about 6 feet thick between the villages of Harri and Manjira. In the upper reaches of this river there are indications of coal in four or five places of which only two are worth mentioning—one a mile to the north-east of Kurdih and another half a mile to the south of Mulichua, the dip of the beds being about 5 degrees in a northerly direction. In the Tanki stream which meets the Katna near Majouli no outcrop has been noticed.

Gohirari River.

The Gohirari river takes its origin in the Mahora Hills forming the trap and supra-Barakar outlier. The junction of this river with the Son lies among the Talcher rocks over which it flows for nearly three miles. There are many outcrops in this river but none of them contain a seam having a thickness greater than 3 feet. The first series of outcrops is met with between latitudes 23° 10′ and 23° 12′. In this part there are three outcrops in the Gohirari and one in the tributary stream Thima All four outcrops lie to the south of Dhuma village. Further up, there are three more outcrops in the feeders near Reula, Pakariha, and Ledara; and in the main stream there are four more—two near Murdhoa, one near Semariha, and one near Sardih. In the upper reaches of the Gohirari there is an outcrop in a tributary stream near Chinmar and three outcrops to the south and west of Taraidol.

Tributaries of Kaser.

In the area which is being described, viz. that between longitudes 81° 45′ and 82° 5′ there is a small tract of land which is drained by tributary streams of the Kaser Nadi. In this small patch there are two outcrops—one to the north of Bacharuar and the other to the east of Kureli. Further towards the north there is another outcrop not far from the village of Janari.

Kunuk River and its tributaries

We have already noted an outcrop of coal at the confluence of the Kunuk Nadi with the Sone River. The next noticeable outcrop in the Kunuk is nearly 20 miles from this junction close to its meeting place with the Dhoran stream This outcrop contains a 4-feet seam of coal. For about 8 miles further up the river there is no trace of coal In the upper reaches of the Kunuk and

in the small feeders coal outcrops in eight or nine different places. There is one outcrop in the Bichi Nadi, another in a small stream near Kichri, and one near the village of Chatai. There are five outcrops in the stream which rises not far from Delbhakherua three of which are close to its source, one near its junction with Kunuk, and one midway between the source of the river and its junction with the Kunuk. None of these outcrops are of much importance. The only outcrop worth noting is that which is exposed between the villages of Khamaria and Semiria in a small stream which takes its rise near the latter

Area to the east of longitude 82° 0′ Kewai River outcrop.

The coal-bearing area within Rewa State lying to the east of longitude 82° 0′ is drained mostly by the river Kewai and its tributaries Chauruar, Kanai, Latbura, Koki, Barne, and their feeders. Commencing at the lower reaches of the Kewai where it meets the Son about two miles west of the boundary between the Rewa State and Pendra District, it is observed that in this part both the rivers flow through the Talchir rocks. After winding its way for two miles in a N.N.E. direction the Kewai enters the Barakars. Two miles further up there is an outcrop of coal to the north-west of Gambhirua village. The scenery of this particular part is very bold and strikingly characteristic. A number of pot-holes in the coal-measure sandstones clearly show the eroding action of water. Further up, to the west of Belha, there are two outcrops—one about a quarter of a mile from the village and the other on the left bank of the river. In the latter there is seven feet of coal with parting of coaly shale nearly a foot thick. An analysis of a sample of this coal gave a high percentage of fixed carbon, as will be seen from the following:—

Volatile matter	.. . ..	25 49
Fixed carbon	. . ..	63 54
Ash	.. . .	10·97

Further up the river there are signs of coal at the mouth of the stream which flows near Katma. Then for 10 or 12 miles no outcrop is visible either in the Gohirari or in the subsidiary streams

Charuar Nala outcrops

In the bed of the Kewai River there are no other outcrops within the limits of the Rewa territory, though there are a few outcrops in the part which flows through Korea State. The Kewai River forms the boundary between the Rewa and Korea States for nearly seven miles from its union with Barne Nala near Bichia.

Koki Nadi outcrop.

In the Koki stream which meets the right bank of the Kewai there are outcrops in two places, one near the union of the two streams and the other about a mile and a half to the north-west of that point. There is another exposure in a small feeder to the north of Gurudand. In another feeder-stream which flows past Bhalmari on its northern side there is one more exposure of coal.

Kanai Nala exposures

Another tributary of the Kewai, which is of some importance, is the Kanai with its minor tributaries the Bichi and Jengurada There are many outcrops of which only four are in Rewa territory and even these are not of much significance, the seams being under 3 feet. These outcrops are situated near the villages of Thangaon, Bachani, Kanai, and Balgaon.

Another stream in this area which deserves consideration is the Hasia which forms the boundary between Rewa and Korea for two miles. In this stretch, there are three

outcrops of coal. According to Lala Hira Lal (Hughes' colleague), the first outcrop in the Hasia Nadi to the north of the trappean dyke contains 16 feet of coal. Whether the whole thickness contains good quality coal or whether the seams are interstratified with shaly material also, is not known.

Hasia Nala outcrops on the Rewa-Korea boundary

Although the Hestho River flows outside the boundary of Rewa State some of its tributaries have their source in Rewa territory and in which coal is found to outcrop in a few places. Such for instance is the Kulharia stream in which coal outcrops near Bhalmuri. There is another exposure near the union of the Jhiria with the Kulharia. The first of these, viz. the Bhalmuri seam measures 5′ 4″. The second exposure contains the lower seam of coal which consists of two bands of coal 3′ 6″ and 2′ 8″ separated by a parting of one foot of coaly shale.

Kulharia outcrop.

VII. Singrauli Coal-field.

This coal-field derives its name from the small principality of Singrauli which formerly belonged to a powerful Zemindar of the Khairwar tribe. The Zemindar died without an heir and his estates were acquired by certain Venuvanshis of Allahabad, who were the founders of the family of the present Rani of Singrauli. The Rajas of Singrauli were formerly subordinate to the Raja of Bardi, one of whom made over the Singrauli Ilaka to Maharaja Jai Singh, great-grandfather of the late Maharaja Sir Venkat Raman Singh.

Boundaries.

Although this coal-field is known by the name of Singrauli coal-field it must be made quite clear that only its eastern part lies in Singrauli Ilaka. The coal-bearing formations cover about 900 square miles. They stretch over about one degree of longitude from 81° 48′ to 82° 48′, the distance between the eastern and western extremities being 64 miles. In a north to south direction they cover 28 miles, the extreme points lying between latitudes 24° 12′ and 23° 47′. The westernmost extremity is close to Marwas The villages Kamarji, Chiri, Jir, and Malgo are on the southern boundary of the coal-field while Tal, Kachinar, Bichiadal, Deosar, Jagober, and Gorbi are on the northern boundary. Among the coal-bearing rocks there is an outlier of Mahadeva rocks between latitudes 24° 22′, 24° 11′, and longitudes 82° 3′, 82° 11′ The northern part is bounded by gneissic rocks while the southern and south-western portions are fringed by Mahadeva rocks. In the south-east area the Talchirs are exposed while to the east the

coal measures run for some miles beyond the boundary of Rewa State.

Previous observers

Captain Wroughton was the first to discover coal near Kota in 1840. Trial pits put down near this place disclosed seams of coal aggregating to about 5 feet in thickness. It is stated that during the forties and fifties of the 19th century coal was mined near Kota and Parari in Singrauli and was carried to Mirzapur over very bad roads for a distance of about 80 miles. The coal was sold for use on the Ganges steamers. From reports made on this coalfield by W. Roberts in 1855 and by D. Smith in 1857 it appears that the outcrop of coal near Ghuraoli, two miles to the north of Naunagar, was discovered at that time, as also the outcrops to the S W. of Koelkut and Raondi between Parari and Kachra. The first outcrop is stated to occur at Toorah but in the large trigonometrical survey maps (scale 1 inch = 1 mile) no such village is marked The writer of these notes found this outcrop two miles north of Naunagar in the hill range (composed mostly of Barakar rocks) which runs for nearly 15 miles in an east to west direction. The thickness of the coal at the outcrop was found to be 8 feet. About a hundred yards to the north of the outcrop an old pit having a diameter of about 7 feet was seen. The pit which seemed to be more than 50 feet deep is in a good state of preservation. It was evidently sunk for one of two reasons—either for trial purpose or for taking out coal from some of the lower seams. None of the local men could give definite information on this point.

Outcrops of coal.

The important outcrops of coal hitherto found occur chiefly in the eastern part of the coalfield. The following shows the exact

locality of the various outcrops which occur in this field:—

(1) About 2 miles due north of Naunagar, in the Ghuraoli Hills (24° 8′ : 82° 39′).

(2) About a mile to the east of the Trigonometrical Station of Ghuraoli.

(3) Near the boundary line between Rewa State and Mirzapur and about a mile to the S.W. of Onrawa (24° 9′ : 82° 42′)

(4) Three miles to the N.E. of Tulda and about 1½ mile to the S W. of Thurwa (24° 11′ : 82° 35′).

(5) 2¼ miles S.W of Koelkut and 1½ miles south of Parari (23° 55′ : 82° 30′ 30″)

(6) ¾th of a mile west of Kachra (23° 52′ : 82° 31′ 30″)

(7) 2½ miles due west of Chitouli (23° 53′ 30″ · 82° 32′).

(8) In the stream near Amlei (24° 2′ : 82° 29′)

(9) In the Bandha Nadi about half a mile to the south of Ujehni (24° 10′ : 82° 25′).

(10) In a feeder of the Mohan River close to Ubri (24° 9′ · 82° 20′) [mostly carbonaceous shale].

(11) Between Katdaha and Paraidol (24° 11′ : 82° 15′) [mostly carbonaceous shale].

The outcrops near Naunagar, Koelkut, Amlei, and Ujehni are important. The outcrop in Ghuraoli Hills north of Naunagar consists of a seam of coal about 8 feet thick. The seam near Koelkut and Parari (otherwise known as Pudri) measures about 6 feet in thickness while the Amlei and Ujehni seams measure 5½ and 6 feet respectively.

After the discovery of coal near Kota in 1840 by Captain Wroughton it appears that the coal seams near

that place were worked for some time but it is not definitely known for how many years these mines were worked. According to D. Smith coal was being quarried at Pudri (Parari) in 1857 the thickness of the seam being 21 feet. The last attempt at mining coal in Mirzapur District was made in 1896, when about 1,000 tons of coal was produced.

The average composition of two specimens of Kota coal obtained by Wroughton was as follows:—

Volatile matter . . .	43·35
Fixed carbon .	54·65
Ash . ..	2·00

The results of analyses of Singrauli coal found by R. D. Oldham of the Geological Survey of India were stated to be disappointing and to have given poor results.

In the opinion of the writer it is extremely likely that the two specimens of coal obtained by Captain Wroughton which gave a remarkably low percentage of ash (2 per cent) were specially selected, whereas the specimens collected by Oldham probably consisted of weathered specimens mixed with carbonaceous shale. The following are results of analyses of carefully sampled specimens of Parari and Naunagar coal:—

	Parari Coal. (near Koelkut)	Naunagar Coal
Moisture .. .	5 68	6·28
Volatile matter	28 14	26·62
Fixed carbon	52·72	49·42
Ash	13·46	17·68

VIII. Possibilities of Development of the Johilla, Sohagpur, and Singrauli Coal-fields.

In discussing the possibilities of development of the coal-fields of Rewa State the first consideration is whether there is likely to be a large demand for the class of coal which occurs in Johilla, Sohagpur, and Singrauli. It will be seen from the appendix that the calorific values of coal from the Rewa State coal-fields range from 5,000 to 6,500 calories. The quality usually met with has a calorific value of about 5,500 calories. The best varieties of Bengal coal have a calorific value of about 13,000 B.T.U. which is equivalent to about 7,220 calories. Rewa coal (by which is meant the coal from any of the Rewa State coal-fields) may, therefore, be called a good second-class coal without any fear of contradiction. The question now is, whether there is any great demand for coal of this quality. Judging from the number of applications which have lately been received by the State for leases of coal near Burhar, Anuppur, Sohagpur, and Birsingpur, and the keenness evinced by many of the applicants to secure the leases it is evident that this coal has a fair demand. The demand for this kind of coal has increased considerably of late and there is every reason to suppose that the demand for coal from Umaria and adjacent coal-fields will go on increasing. The G.I.P Railway Co. have been the chief customers of Umaria Colliery for years past Whatever coal the Umaria Colliery can spare finds a ready market, principally, in Katni and Sutna, and to a less extent, at Maihar, Jubblepore, Allahabad, and other places.

There is no doubt that coal of the kind which occurs near Semra and which is exposed in the Jamunia stream

(in the Sohagpur coal-field) will find a ready market anywhere as their calorific value is high, ranging from 6,200 to 6,500. Such coal will stand long transportation also Coal having a calorific value of from 5,200 to 5,700 will naturally have to compete with coal from the Chhindwara (Pench Valley) coal-field and Wardha Valley coal-fields which are nearer to Nagpur, Akola, Umraoti, Bhusawal, Khandwa, Indore, and other places where there is a fair demand for coal With the development of the Johilla and Sohagpur coal-fields new markets will, certainly, have to be tried. There is a great demand for coal in Ahmedabad, Broach, Viramgam, Baroda, and many places in East and West Khandesh where it is largely used in cotton mills, cotton presses, and ginning factories.

Need of a ıailway.

There is one point to which the writer would like particularly to draw the attention of those in authority and that is, the need of a railway in many parts of the State, specially in the area covered by the coal-fields. A railway from Burhar or Anuppur *vıa* Rampur, Jaintpur, and Chitraon to Beohari and thence to Pipra through Amgaon, Garwani, and Parari would open up some parts of the Sohagpur and Singrauli coal-fields. This subject has been discussed at length by the writer in his notes on Rewa State Corundum.

Establishment of ındustries which are dependant on cheap electric power.

The immense store of coal which nature has bestowed upon Rewa State could be made use of in the establishment of industries in which electrothermal and electrolytic processes are employed and which depend for their existence solely on cheap electric power. The most important of these industries aıe the manufacture of aluminium from bauxite; of carborundum from sand and coke; of graphite from

anthracite, and of calcium carbide from lime and coke. The production of electric power by means of large steam turbo-generators has been dealt with in detail by the author in Part IV on the Possibility of Manufacture of Aluminium in Rewa State.

PART II.

REWA STATE CORUNDUM.

INTRODUCTION, PART II

Beyond a brief description in Part I. of the Economic Geology of India, on Corundum, by Sir Thomas Holland, no other references on Rewa Corundum are available. The first geologist to visit the corundum deposit in Singrauli on the Mirzapur border was Mr. Fred. R Mallet of the Geological Survey of India. He examined the corundum outcrop, first in 1872 and again in 1873, and summed up his impressions about it in volumes V and VI. of the "Records of the Geological Survey of India" in his brief notes on the Mineralogy of South Mirzapur and Adjoining Parts. These volumes are, however, out of print and not available to the public. As State Geologist, Rewa State, I had exceptional opportunities of examining and studying the Rewa corundum deposit I have, therefore, thought it fit to record my observations, both in the field and in the laboratory, in the form of a memoir in the hope that it will be of some service to the Rewa Durbar and to geologists and others desiring reliable information upon the subject. For the purpose of comparison and with a view to increase the usefulness of the memoir, short descriptions of important corundum deposits of India and other parts of the world are given. A chapter is devoted to artificial abrasives The industrial applications of corundum are dealt with in a separate chapter

PART II.

REWA STATE CORUNDUM.

IX. Physical Description.

Situation and boundaries

This interesting mineral deposit is situated near the village of Pipra (Lat. 23° 58′: Long. 82° 44′) in Singrauli. About six miles due east of Pipra is the boundary line separating Rewa State from Mirzapur District. Due south of Pipra the State boundary terminates at a distance of about five miles, the part beyond lying in Sarguja. The Rehr River, which is situated to the west of Pipra and is only about a mile distant from it, flows in a northerly direction for about four miles and thence takes a turn towards the east. The parts to the west and north-west of Pipra all lie within the State boundary and mostly consist of Barakar rocks which are the chief coal-bearing formations of India.

Physical aspect

The country adjoining Pipra is hilly and covered with a thick forest, specially those parts which cousist of old crystalline rocks. Bamboos grow plentifully in these parts, some of which are so verdant that Pipra was long known as the favourite resort of tigers. Two years ago the part near the corundum deposit had been cleared of much of the undergrowth and jungle Since then, the tigers seem to have left Pipra for shadier nooks and more peaceful corners. The Rehr River with its ever-flowing waters and its cascades, its picturesque jungle-covered banks, its

lake-like enclosures and sandy prominences where crocodiles bask peacefully in the sun, adds much to the natural beauty of the place.

Relation of geological formations to scenery

It is a known fact and one which has been observed by many geologists that the scenic effect of any particular tract of land depends to a very large extent on the geological formations of that part. This relation of the geological formations to scenery is very marked in many parts of the Rewa territory so much so that it would not be difficult for a practised eye to guess correctly the nature of the formations that would be met with by observing the nature of the vegetation and noting the broad scenic features. The Vindhyans, Barakars and Supra-Barakars, the Talchirs, and the transition and crystalline formations, all, display characteristic peculiarities of their own. The old crystalline formations and the transitions are well adopted to retain moisture and all kinds of trees and undergrowth flourish on them whereas the Vindhyan rocks, which are exposed in more or less parallel ridges which are well drained, are only sparsely covered with trees which are either thorny or have a scanty foliage. Thus, for instance, many of the low ridges in the Sone valley where the porcellanic formations are largely exposed present a very characteristic appearance. These hills are covered mostly with Salai trees (Boswellia thurifera and Boswellia serrata). During certain seasons they present a barren aspect due to the scanty foliage of the trees and could at once be spotted out by their general appearance (Plate I, Fig. 1).

The fact that certain trees prefer one kind of soil and avoid others has been stated by T. W. H. Hughes also in

FIG 5.

Typical scenery of the Porcellanic Formation.

Photo. K. P. Sinor.

Vol. XXI, Part III, of the Geological Survey of India. He mentions therein that Shorea robusta or Saré which grows in all situations is not a lover of trap rock and avoids soil in which the special constituents of trappean matter preponderate and that its place is taken by Boswellia or Salé. He says, "So frequently is this a significant circumstance that I have often been led to the discovery of some dyke or run of trap by noticing the presence of this tree."

Geological formations of Singrauli.

The undulating hills and thick forests so characteristic of Pipra, Bardghatta, Karkota, and other parts lying within the zone of old crystalline formations are overlain to the north and west by level stretches of land consisting of Talchir rocks A large part of this area is under cultivation. The trees which abound in the waste land consist mostly of Butea frondosa which is locally known as "Chhiola" and Acacia catechu locally known as "Khair" The former is the principal lac producing tree while the latter is the source of catechu or "Kattha." The Talchirs are in turn covered by the Barakars. These, which are the principal coal-bearing formations of India, consist of ranges of sandstone hills fairly covered with jungle in this district. Thus, there are three chief types of geological formations in Singrauli, viz. the Talchirs, the Barakars, and the crystallines. The corundum deposit occurs in the last mentioned formation.

X. Historical Notes on Rewa Corundum.

Early history of the corundum mines.

Very little is known about the early history of the corundum mines at Pipra. Doubtless, these mines have been worked in olden times, but no definite information on this point is available. This much however is known with certainty that in the early part of the 19th century corundum used to be exported from Mirzapur to various places, specially, the north-western parts of India. What was the average annual output of the mines or where the corundum was ultimately used is also not known but it is reasonable to suppose that a large part of corundum was used in India in the manufacture of corundum wheels, as the trade of the armourers locally known as 'saikalgars' was then very brisk.

Early literature on Rewa corundum

Dr. Francis (Buchanan) Hamilton was the first to give a short account of the corundum deposit at Pipra, in Rewa State, in the Edinburgh Philosophical Journal (Vol. II., Page 305) in 1820. He had not seen the deposit but obtained his information at Mirzapur in 1814. The trade in corundum appears to have been very brisk at that time.

In 1845, Captain W. S. Sherwill mentioned this deposit in Vol. XV of the Journal of the Asiatic Society of Bengal. He was also unable to visit the locality. According to him, the mines were worked only once a year, when just enough corundum to supply the wants of the traders was extracted. The mineral had to be sent on pack-bullocks and the greater part of western India was supplied with corundum from the Rewa deposit. Accord-

ing to Captain Sherwill, there was a belief, then current, that the rock at Pipra was turned into corundum, by the will of the gods, for one day only in the year, a myth invented by the traders to prevent pilfering, as shrewdly guessed by Sir Thomas Holland.

Fred R. Mallet, of the Geological Survey of India, had visited the locality and examined the corundum deposit first in 1872 and again in 1873 and had described it in his "Mineralogical Notes on the Gneiss of South Mirzapur and Adjoining country" in Vol. V, Part I (1872) and Vol. VI (1873) of the Records of the Geological Survey of India. The description given by him in these volumes agrees in the main with the writer's observations though there are points of difference here and there, specially regarding the nature of the various rock-types found in this area. This is what might naturally be expected as the petrological microscope was probably little known and very little used at the time when he wrote his notes. Considering his short stay and the jungle-clad nature of the country the work he had done in this part was quite good. Mr. Mallet mentions that it was customary before commencing mining operations to propitiate the guardian spirit of the mine by sacrificing a kid This practice is current even at the present day before mining operations are undertaken, specially, when the mines have lain dormant for some time

The next mention of Rewa corundum is found in the admirable treatise on corundum by T H. Holland (now Sir Thomas Holland) published in 1898. In this treatise he has given a resume of Mr. Mallet's notes on this deposit and early references by Dr Francis Hamilton and Captain Sherwill.

XI. Mineralogical Characters of Corundum.

With the exception of the diamond, corundum is the hardest of all minerals It occurs in three chief varieties .—

(1) Precious corundum ; varieties Ruby, Sapphire, and other transparent, coloured, or water-clear gem-stones.

(2) Common corundum or Adamantine spar.

(3) Emery

All these varieties, though differing widely in their external appearance, are identical in their essential characters, viz chemical composition, hardness, specific gravity, and other physical characters.

Ruby and sapphire are the gem varieties of corundum. Ruby consists of pure aluminium oxide corresponding to the formula Al_2O_3, but it contains in addition small quantities of chromic oxide which is the cause of the rich-red hue or the highly prized tint known as pigeon's blood, a shade of red somewhat inclined to purple. Sapphire is identical in composition with ruby, but the beautiful blue colour is due to minute quantities of titanium oxide. Besides these two precious varieties there is another which from its yellow colour is known as oriental topaz, the colouring material in this case being a minute quantity of ferric oxide. The transparent varieties of corundum which are of a green and violet colour are respectively known as oriental emerald and oriental amethyst. When quite pure, crystallized corundum is perfectly colourless and transparent.

Common corundum

Opaque and cloudy corundum, whether in the crystalline or massive state, is known as common corundum as distinguished

from precious corundum. The opacity is mostly due to inclusions of foreign minerals, though in the case of some large well formed crystals mechanical stresses might be responsible for the destruction of transparency.

Emery

When the corundum is granular and mixed with a considerable amount of foreign matter, especially magnetite and hematite, it is known as emery

Crystal form of corundum

Corundum is a dimetric sesquioxide of aluminium and belongs to the hexagonal (rhombohedral) crystalline system It occurs mostly in six sided pyramids, scalenohedrons, and prisms. Rhombohedrons and basal pinacoids are rarely seen Pyramidal crystals with or without basal plane are more common The Burma rubies generally show rhombohedrons and basal planes in combination with the prism faces, whereas the sapphires of Cashmere show steep hexagonal bipyramids The common corundum of Madras also shows the latter form Second-order prisms and second-order pyramids usually preponderate Sometimes the crystals occur as hexagonal plates This usually happens when the crystals have separated from igneous fusion. Crystals from alluvial deposits being much water-worn appear barrel shaped.

Anhedral crystals

Besides the euhedral forms above described corundum also occurs in the shape of granules with irregular outlines, that is, in the anhedral or allotriomorphic form. The massive corundum of Rewa consists mostly of the anhedral forms of crystals in a microscopic state

Twinning.

Corundum crystals frequently show twinning, the unit rhombohedron being the twinning plane Polysynthetic twinning

is common, but penetration twins occur only rarely. Thin sections of Rewa corundum show, clearly, the polysynthetic twinning under the microscope, between crossed nicols.

Cleavage and fracture

Regarding cleavage there is some difference of opinion. According to some authors there is cleavage which is parallel to (0001) due to which corundum crystals show a tendency to split parallel to the basal plane But according to Prof. Judd and others these separation planes are not due to a true cleavage but to incipient alteration along these directions. Such alteration is very common parallel to the basal plane and to some extent parallel to the rhombohedron The pearly lustre on what are usually known as the cleavage faces of corundum has also been described by Prof. Judd to chemical changes resulting in the formation of thin films of decomposed material. The fracture of corundum crystals is uneven to conchoidal.

Optical properties.

Corundum is optically negative (-), with rather strong refraction but weak double refraction($\alpha = 1 \cdot 759$; $\gamma = 1\ 768$; $\gamma - \alpha = \cdot 009$). The interference colours are, therefore, of the 1st order, and resemble those shown by thin sections of quartz which also has a week double refraction ($\gamma - \alpha =$ 009).

Colour.

Corundum is at times colourless, but very often it is coloured. The colour may be red, blue, green, yellow, brown, pink, purple, and grey Rewa corundum exhibits the last three colours

Specific gravity.

Common corundum has a specific gravity of about 3·95. Ruby has a specific gravity of 3·98; and sapphire, which is also the

hardest of the three, has a specific gravity of 4·1. It appears that with increase of hardness the specific gravity also increases. Corundum which has undergone a certain amount of chemical change has a lower specific gravity than pure corundum The specific gravity of the best specimens of Rewa corundum has been found to be 3 94 Some specimens of Rewa corundum examined by Prof Judd were found to have a specific gravity which varied from 3 84 to 3 88. Evidently these samples were not of the best quality The specific gravity of samples largely admixed with sillimanite and fuchsite is considerably less and varies according to the percentage of the impurities.

Asterism

Some gem varieties of corundum show a six-rayed star due to narrow lines of light emanating from a centre and radiating at angles of 60°. Such stones are known as star-sapphires or star-rubies. This effect might be due to the inclusion of rutile needles in the crystal, arranged in three directions parallel to the edges (0001) (1120) or it might be due to tube like cavities regularly arranged in the crystal at angles of 60° in planes at right angles to the crystallographic axis.

XII. Specific Characters of Rewa Corundum.

Form and composition

Rewa corundum is not found in the form of large and well defined crystals similar to those found in the Madras Presidency and Mysore State in India, and, in Madagascar, but occurs in the massive state (Plate II, Figs 2 and 3) In this respect Rewa corundum resembles the massive rock corundum which occurs at Nongryniew in the Khasi Hills in Assam The best specimens of Rewa corundum are more or less free from other minerals such as fuchsite, rutile and magnetite. Specimens containing a large amount of sillimanite and tourmaline in addition to the minerals above mentioned are not uncommon. Some specimens found in Karkota, a village about four miles distant from Pipra, consist of a few tiny crystals, the prism faces of which show characteristic striations It is likely that in the druses of some large water-worn boulders of corundum the crystalline variety may be found. Being free from stresses such crystals are likely to approach the gem variety of corundum. Hitherto, however, well defined crystals of corundum of the gem variety have not been observed anywhere in Pipra or Karkota.

Chemical composition.

As Rewa corundum occurs in close association with microscopic grains of iron ore, rutile, tourmaline, and fuchsite, its composition varies in different specimens. In fact, we are here dealing not with a single mineral, but an aggregate of minerals variously admixed and, therefore, without a constant composition. Good quality Rewa corundum consists of from 90 to 94% of alumina. The adjoined table gives the analyses of three specimens of

FIGS 6 and 7

the purplish variety It should be noted that all the corundum which occurs at Pipra is not of this quality. There is some corundum which is intimately mixed with rather a large quantity of sillimanite, green mica, and tourmaline. This is, of course, useless as a marketable commodity, unless the pure corundum occurring therein is sorted out by crushing and concentrating However, such a contingency is not likely to occur for some years to come.

Table showing the Analyses of three specimens of Rewa Corundum of the purplish variety.

		Analysis by Imperial Institute, London	Analysis by D. J Williams and Co , London	Analysis by R V Briggs Calcutta
		Per cent	Per cent	Per cent.
Alumina	.. Al_2O_3	93 38	93 91	89 28
Ferric Oxide	.. Fe_2O_3	0 32	1 19	4 22
Ferrous Oxide	.. FeO	0·99	—	
Manganous Oxide	. MnO	trace	[illegible]	—
Titanium Oxide	.. TiO_2	0 60	[illegible]	—
Lime	.. CaO	absent	[illegible] 18	1 63
Magnesia	.. MgO	0·62	—	1 08
Silica	.. SiO_2	3·81	2·70	3 68
Loss on ignition	..	0 76	0 95	0·11

Under the microscope, Rewa corundum is found to consist mostly of minute grains and short lath-shaped crystals of corundum together with a small quantity of magnetite and rutile. Occasionally minute crystals of sillimanite, andalusite, and tourmaline are also found. Some of the corundum crystals show polysynthetic twinning. The minute

Micro-structure.

grains and crystals of corundum are interlocked, which makes the mineral exceedingly tough

Phosphorescence

Rewa corundum has the peculiar property of emitting crimson light when struck. This property known as phosphorescence is common to all corundum but is shown in a marked degree by the Rewa corundum.

Pleochroism

Rewa corundum being opaque it is only in thin sections of this mineral that pleochroism is observed. The colours observed are very pale pink and faint yellow. Sections of the usual thinness do not show it so well as somewhat thick sections. In some of the sections of Rewa corundum a sort of patchy pleochroism showing rich rose-red and faint greenish-yellow tints was observed This is, undoubtedly, due to the presence of andalusite which is occasionally present in minute quantities in the Rewa corundum.

XIII. General Geological and Economic Features of the Rock Formations at, and near, Pipra in Singrauli.

The geological formations at, and near, Pipra belong to the old crystalline rocks and consist mostly of gneisses and crystalline schists. They belong to the newer type of gneiss which is known to Indian Geologists as Bengal Gneiss and which is well developed to the south of the Vindhyan basin in Rewa, Mirzapur, and Behar It differs from the old or the Bundlekhund gneiss in the absence of quartz-reefs and basic dykes, the comparative frequency of beds of crystalline limestone and dolomite, and to the great prevalence of accessory minerals Bundlekhund gneiss is traversed by long narrow ridges composed of quartz-reefs running for miles and having a N.E. to S.W. trend in general. It is also characterised by the total absence of limestone and dolomite beds, and has been found to be very poor in accessory minerals. Structurally, also, the two types of gneiss present important points of contrast The Bundlekhund gneiss is massive and homogeneous and the foliation is obscure, while in the Bengal gneiss the foliation is quite distinct and seems to coincide with the original lamination of the beds. These are the chief points of difference between the two types of gneiss.

The exposure of gneissic rocks near Pipra is characterized by many bands of hornblende schist. Quartz schist and mica schist also occur. Bands of crystalline limestone and dolomite having nearly the same trend as hornblende schists are found to penetrate the gneiss in a few places The variety of minerals met with in the gneiss of the Rehr valley is fairly large but with the exception of corundum and magnetite no other mineral or ore has

6

been found in workable quantities. Magnetite occurs in beds in the gneiss near Kadopani and at Mainadhye which are situated at distances of about two and six miles respectively from Pipra. The Mainadhye ore consists of 56 per cent of iron. The Kadopani ore is largely admixed with quartz and other minerals Muscovite occurs at a place known as Bardghatta two miles due east of Pipra in a tourmaline-quartz-mica pegmatite. The size of the mica plates is not large enough to make the occurrence economically important. It is probable that further exploration work might reveal good mica plates of fairly large size.

The main rock of this area is a porphyritic gneiss consisting of potash felspar (mostly microcline with some orthoclase), biotite, and quartz Epidote veins have been observed to run through some of these, but this is neither a general nor a widespread characteristic From the porphyritic to the finely crystalline granitoid gneiss there are various gradations Coarser types also are represented by pegmatites which consist of quartz, felspar, mica, and tourmaline In some fine-grained granitoid gneisses garnet and sillimanite occur largely in addition to the minerals mentioned above. This garnet-sillimanite rock occurs in close association with the corundum bed

Another important rock which occurs in this area is a fine grained pyroxenic rock in which the minerals seem to have undergone crushing. Enstatite is the chief mineral in this rock, other minerals being biotite, quartz, plagioclase felspar, and magnetite. Another rock which occurs in close association with the corundum bed is a schistose rock consisting mainly of quartz and sillimanite with a few grains of rutile. A modified form of this rock contains euphyllite, tourmaline, and andalusite in addition to sillmanite, quartz, and rutile. A number of interme-

diate forms occur in which the proportion of these minerals differs greatly. A highly basic rock containing a lot of garnet and black mica occurs very near the corundum outcrop, also a hornblendic rock compact in hand specimen but which shows a certain amount of schistosity under the microscope. Another basic rock consists mostly of pyroxene and felspar, some of the former having changed to hornblende The rocks exposed in the bed of the Rehr River about half a mile from the village of Karaonti and about four miles distant from Pipra consist of a few bands of crystalline limestone which has been formed as the result of metamorphism of an originally calcareous rock and contains the characteristic minerals tremolite, serpentine, enstalite, euphyllite, and green grossularite

XIV. Petrographic Descriptions of the Rocks which occur close to, and in association with, the Corundum Bed.

These rocks will be described in the following order :—

1. Porphyritic gneiss.
2. Finely crystalline granitoid gneiss.
3. Finely foliated garnetiferous biotite-gneiss.
4. Pegmatite consisting of quartz, felspar, tourmaline, and mica.
5. Quartz-sillimanite schist containing some rutile and a little tourmaline.
6. Quartz schist.
7. Schist consisting of sillimanite, andalusite, tourmaline, and euphyllite.
8. Bed of massive corundum.
9. Pyroxene granulite.
10. Sillimanite-garnet-biotite rock.
11. Pyroxene felspar rock in which the pyroxene is in various stages of alteration to amphibole.
12. Hornblende schist.
13. Vein rock resembling halleflinta.
14. Brecciated rock resembling porphyry.
15. Crystalline limestone consisting of tremolite, serpentine, green grossularite, biotite, and euphyllite.

---

1. Porphyritic gneiss.

The minerals which enter into the composition of the porphyritic gneiss which occurs near Pipra consist of quartz, orthoclase, microcline, biotite, minute crystals of red garnet, and small quantities of hornblende and epidote.

FIG 8.

Eyed Gneiss showing typical fluxion and lenticular structures.
Ordinary light. Magn 28.

FIG 9

Photo-micrograph of finely foliated granitoid Gneiss consisting essentially of quartz, microcline, and orthoclase
Crossed nicols. Magn 40.

Photo. K. P. Sinor.

The quartz, felspar, and mica are arranged in parallel lenticular folia, the biotite plates of two layers uniting with each other on each side of an aggregate of felspar crystals which assumes the shape of an eye. The felspathic layer is thus cut up into a number of isolated eyes (Plate III, Fig 4). The crystals of microcline are usually of a pink colour ; those of orthoclase show some shade of red or pink, and often have white colour The oligoclase crystals are always of a white colour and show polysynthetic twinning under the microscope The general appearance of this rock depends largely on the proportion of the black mica and the size of felspar crystals.

The quartz occurs as clear granules, mostly free from inclusions Both soda and potash felspars occur, the latter being greatly in excess of the former. The mica consists of biotite which appears either brown or green in thin sections, mostly the former. It is of a highly pleochroic variety The garnet is of a deep red colour in hand specimens. In thin sections it appears of a light pinkish-red colour and shows a number of inclusions. Other ferromagnesian minerals present in this rock are hornblende and epidote. In some sections, small quantities of enstatite have been observed. The hornblende is of a greenish brown variety and is highly pleochroic.

2 Finely foliated granitoid gneiss

Besides the porphyritic variety above mentioned there is another variety of gneiss which has a finely foliated texture and which presents dark brown, grey, and greyish pink colours In a direction perpendicular to the line of flow, the texture appears finely crystalline like that of a micro-granite. The minerals of which this rock is composed are the same as those which enter into the formation of the porphyritic gneiss described above, with the

exception of hornblende. Although schistose structure is not very noticeable in hand specimens of this rock, thin sections reveal such a structure quite plainly The quartz is seen to be drawn out in long rectangular tablets in parallel lines, the intervening space being occupied by a mosaic of quartz and felspar (Plate III, Fig. 5). Biotite flakes are also disposed in a direction parallel to that in which the quartz crystals have been drawn out.

3 Finely foliated garnetiferous biotite-gneiss.

This rock is only a variety of the above. Besides quartz, microcline, orthoclase, and biotite it consists of a number of minute crystals of garnet which are arranged in a linear fashion in the same way as the other minerals The garnet crystals are run over in some cases by well marked cracks which follow a more or less parallel direction and are mostly at right-angles to the direction of the line of flow. It appears from this that these cracks have a definite relation to the directions in which the shearing and tensile forces had acted on the rock.

4. Pegmatite consisting of quartz, felspar, tourmaline, and mica

Pegmatite veins occur in many places near Pipra, notably at Bardghatta and Mainadhye. There is also a small exposure not far from the corundum bed. These pegmatites consist mostly of quartz, felspar, and tourmaline, with varying quantities of mica, mostly muscovite (Plate IV, Fig. 6). The felspar consists of large crystals of microcline and orthoclase and also of an aggregate of these two crystals in intimate association. The tourmaline is of the black variety known as schorl and occurs as idiomorphic crystals either separately or in radiate bunches. The characteristic striations are very well marked on these crystals.

FIG 10
Pegmatite consisting of quartz, felspar, schorl and mica.
One-fifth natural size

FIG 11.
Photo micrograph of quartz-sillimanite schist showing grains of quartz enclosing needles and slender crystals of sillimanite.
Crossed nicols. Magn. 40.

Photo K. P. Sinor.

5. Quartz sillimanite schist

To the south-west of the corundum bed (see the Geological Map of the Corundum Field) there is a large exposure of quartz sillimanite rock. This rock is of a milk-white colour in hand specimens, is compact, and presents a fibrous and silky fracture when broken The minerals which enter into the composition of this rock are essentially quartz and sillimanite, the former occurring in greater abundance than the latter

The quartz is drawn out in the form of tablets. The sillimanite is also distributed in parallel lines When quite fresh and unaltered the sillimanite appears quite clear in thin sections under the microscope and occurs in the form of very slender minute prisms and as needles, many of which have been enclosed by quartz (Plate IV, Fig. 7). Being prone to alteration these aggregates of sillimanite prism have altered considerably. It is worthy of note that isolated prisms of sillimanite do not seem to have suffered any change but wherever these prisms occur together in matted aggregates the alteration has been found to affect them considerably, so much so that in some cases nothing but a brownish decomposition product remains of the original mineral.

The quartz which is drawn out in long rectangular tablets is quite fresh and encloses slender prisms of sillimanite which was, therefore, the first to crystallise out. Yellowish and brownish-red grains of rutile are of frequent occurrence in this rock; in the allied rock consisting of tourmaline and euphyllite they assume larger proportions The rutile is distinguished by its outlines when the crystals are perfect (its high index of refraction giving rise to dark borders) and by the straight extinction shown by the prism faces. The tour-

maline which is of the black variety known as schorl is subordinate in amount to the rutile, and occurs in the shape of grains and small fragments. Another mineral, which occurs very sparingly in this rock, is andalusite It is a known fact that this mineral occurs in close association with sillimanite and that the two are sometime found intergrown. In the quartz sillimanite rock the occurrence of andalusite is very limited but there is another variety of the sillimanite rock in which there is little or no quartz and which contains a large proportion of sillimanite together with a fair amount of tourmaline and euphyllite in which andalusite occurs in a large measure.

6. Quartz schist.

In the area in which the quartz sillimanite rock is exposed the writer came across a specimen of quartz schist whose micro-structure proved to be very interesting. A description of the microscopic characteristics of this specimen is, therefore, given below.

The most interesting thing in connection with this specimen is the symmetrical arrangement of certain microlites of an undefined nature in the quartz crystals. Under the microscope the quartz seems to have been drawn out in the form of long narrow tablets in parallel lines (Plate V, Fig. 8) This tabular structure appears very pronounced owing to the presence of extremely fine particles either of glass, iron oxide, or some other mineral which have arranged themselves symmetrically in the quartz crystals. Although the quartz crystals do not show any crystallographic boundaries the arrangement of the inclusions gives the clue to their optical orientation. Thus for instance, in a crystal section which happened to be cut perpendicularly to the crystallographic axis, the microlites have so arranged themselves as to produce a perfect

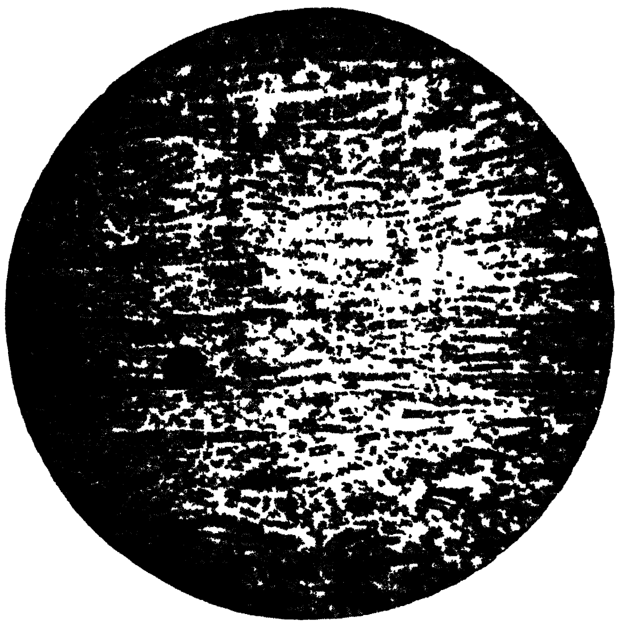

FIG 12.

Photo-micrograph of quartz-schist showing a parallel tabular arrangement of quartz crystals

Ordinary light Magn 60

Photo. K. P. Sinor.

hexagon with equal sides (Plate VI, Figs. 9 and 10). That such a crystal section is truly perpendicular to the crystallographic axis is proved by the fact that it remains dark between crossed nicols when rotated.

In sections of quartz which happen to be parallel to the vertical axis, the inclusions arrange themselves parallel to the sides of a hexagon but in this case all the sides of the hexagon are not equal In fact, the crystallites are seen to arrange themselves in this instance parallel to the crystallographic boundaries of a perfect quartz crystal (Plate VI, Figs. 9 and 10) In this case the crystal is seen to extinguish when the *c*-axis coincides with any one of the cross wires Plate VII, Fig. 11, shows that the inclusions segregate themselves partly in the centre and partly at the margins of the crystal outlines, where, three or four zones are sometimes visible. Exceedingly minute particles are also seen to be radially disposed in a symmetrical fashion from the centre of the crystal section towards the bounding lines. It should be stated that very high magnifying powers even have failed to disclose the nature of the microlites

Symmetrically arranged inclusions in crystals of augite, leucite, garnet, and andalusite have been mentioned in text-books on mineralogy; fluid, liquid, and solid inclusions in quartz have also been elaborately described in many treatises on minerals and rocks; but a case like the present, in which quartz encloses microlites in a symmetrical fashion, has not been mentioned in any text-book on mineralogy or petrography so far as the writer's knowledge goes. Holland in Vol. XXVIII, Part 2, of the Memoirs of the Geological Survey of India has mentioned the case of acicular inclusions in quartz, in his description of the Charnockite series of rocks. He found that the inclusions

crossed one another at angles of 60° and that they lay parallel to the sides of the hexagon in basal sections of quartz. The present case is, however, quite different from that occurrence.

7 Schist consisting of sillimanite, andalusite, tourmaline, and euphyllite.

Besides the schistose rock consisting of quartz and sillimanite there is a similar rock consisting of fibrolite, andalusite, euphyllite, rutile, and tourmaline. The proportions of these minerals vary in different parts of the rock but fibrolite is, in all cases, most abundant. This rock occurs in close association with the corundum rock, mostly forming a fringe to that rock, and, not infrequently, in close contact with it. Andalusite prisms usually occur in clusters and are, at times, seen to be intergrown with sillimanite. They show their characteristic pleochroic extremes, viz. pale yellow-green and rich rose-red colours. In some cases the pleochroism is patchy, though in the majority of cases it is well defined and restricted to definite crystal boundaries.

The green mica which occurs intimately mixed with other minerals in this rock was found by Mr. Mallet to belong to the variety known as euphyllite. In thin flakes it is nearly colourless or of a faint greenish tint. When occurring in platy aggregates it exhibits a pale apple-green colour This mica occurs in the massive corundum itself, usually in the form of thin flakes. It also occurs in platy aggregates round a kernel of corundum. This is not the first instance of corundum occurring in association with euphyllite as these two minerals have been known to occur together at Unionville, in Pennsylvania. Professor Judd had found some fuchsite in the ruby-bearing limestone of Burma and Dr. Lawrence Smith had found green

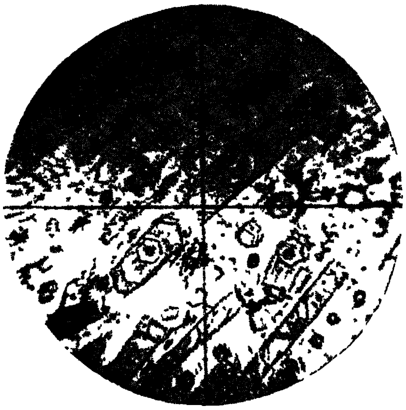

FIG 13

Photo-micrograph of quartz-schist showing symmetrical arrangement of the inclusions. There is a definite relation between the optical orientation of the quartz crystals and the planes along which the inclusions have arranged themselves

Ordinary light. Magn. 240.

FIG 14

Magnified section of quartz-schist showing typical symmetrical arrangement of the inclusions in quartz. The top half of the photo-micrograph shows a crystal of quartz which happened to be cut perpendicular to the C axis while in the bottom half there is another crystal of quartz which happened to be cut parallel to the C axis

Ordinary light Magn 420

Photo. K P Sinor

FIG 15

Highly magnified section of quartz-schist showing radial and concentric arrangement of inclusions

Ordinary light Magn 720

Photo. K. P. Sinor.

mica in the emery deposits of Asia Minor. Both these micas have been stated to be similar to the green mica which occurs with the Rewa corundum.

Rutile occurs as minute grains of yellow and red colour in this schistose rock. It is subordinate in amount to all the other minerals of which the rock is composed It is distinguished under the microscope by its yellow colour (frequently tinged with red) and strongly marked borders due to its high index of refraction. The tourmaline occurs in the shape of small granules and also in clusters of long needle-shaped crystals (Plate IX, Fig 12).

A number of sections of this rock and of the quartz sillimanite schist when examined under the microscope showed that some parts of these rocks had undergone considerable alteration The product of alteration mostly resembles pinite Some cryptocrystalline silica also seems to have separated out from the original minerals.

8. Bed of massive corundum.

The corundum bed is about 700 yards long and from 60 to 80 yards thick. Its length runs almost parallel to the east and west direction On the south-western corner this bed is fringed by quartz-sillimanite schists, pyroxene granulite, and felspar-pyroxene-olivine rock. Euphyllite and tourmaline are in evidence in many parts of the bed. The schist consisting of euphyllite, sillimanite, tourmaline, and corundum occurs in intimate association with this bed and in many cases shows a lenticular habit. The massive corundum itself is composed mainly of microscopic crystals of corundum with varying amounts of sillimanite, euphyllite, andalusite, tourmaline, rutile, and magnetite. The last two occur in greater quantity than the others as is revealed by a number of sections of the massive corundum (Plate VIII, Figs. 13 and 14).

The writer has not come across any specimen which is entirely free from all the minerals mentioned above On the other hand, it should be stated that the best variety consists of 93 to 94 per cent of corundum The specific gravity of the best available specimens of purplish corundum has been found to be 3 94 Specimens of the best 'gulabi' or rose-coloured variety have a specific gravity of from 3·905 to 3 913. The miners distinguish the different varieties by various terms such as Massoorea, Gulabi, Teelia, Dudhia, etc. These terms are respectively used for purplish, rose-coloured, dark, and milk-white varieties of the Rewa corundum The purplish variety is very largely in demand, so is the pinkish variety, though it is somewhat softer than the purple. The Teelia or dark variety owes its colour to the presence of magnetite The milk-white variety known as Dudhia is very impure and is mixed with a large quantity of fibrolite.

As stated in a previous chapter there is a lot of impure corundum mixed with the pure stuff Notwithstanding this disadvantage there is a large quantity of workable corundum. Idiomorphic crystals of corundum small or large have never been observed anywhere in the corundum bed. A specimen of corundum from Karkota about 4 miles to the S.W. of Pipra shows a few very tiny crystals with striated prism faces and with cleavages running obliquely to the striation This particular specimen is of a beautiful purple colour and is enveloped by platy aggregates of green mica (Plate IX, Fig. 15).

9. Pyroxene granulite.

To the W.S.W. of the corundum bed there is a hillock in which pyroxene granulite is found to occur. This rock is also seen in a few places to the S.W of the corundum bed. It is of a dark-grey colour, having a

FIG 17

Photo micrograph of a section of massive Corundum, Pipra The clear spaces represent corundum while the dark grains and patches show oxides of iron

Ordinary light Magn 40.

FIG 18

Another section of the massive Corundum of Pipra Besides corundum and iron-oxides this photo-micrograph shows a few crystals of andalusite and sillimanite In the centre of the figure there is a long slender crystal of andalusite

Ordinary light Magn 40

Photo K P Sinor

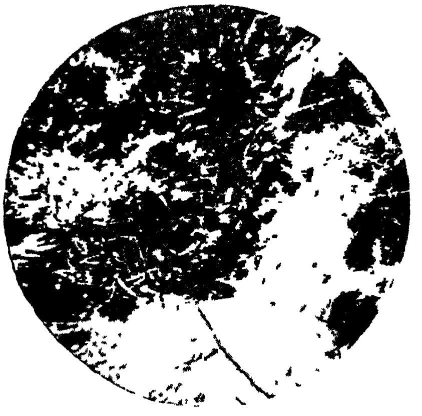

FIG 16.

Schist consisting of tourmaline, euphyllite, sillimanite and rutile In the photomicrograph the dark crystals are those of rutile and the greyish coloured, those of tourmaline The clear space at the bottom and to the right consists of euphyllite. Sillimanite occurs in the shape of needles and matted aggregates

Polarized light Magn 28

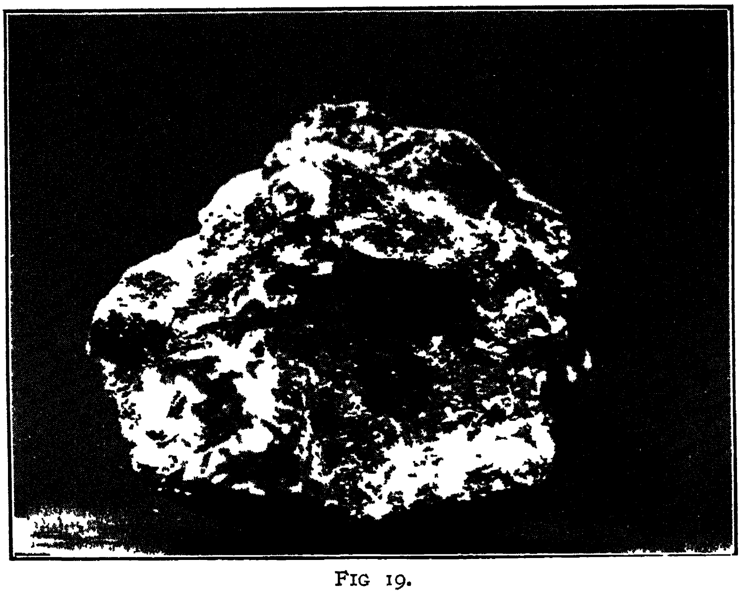

FIG 19.

Photograph of Karkota Corundum consisting mostly of purple corundum and the green mica euphyllite. The dark central part seen in the photo consists of corundum while the green mica surrounding the corundum has come out white

One-half natural size.

Photo. K. P. Sinor.

greenish or purplish tint in some cases. It is very tough and compact, and from hand specimens it is impossible to arrive at any conclusions regarding the minerals composing it. In a few cases, crystals showing schiller give some clue to the presence of a rhombic pyroxene.

Under the microscope this rock is found to consist chiefly of enstatite, quartz, and felspar, with varying amounts of a pale green hornblende, a highly pleochroic biotite mica, and some magnetite Enstatite occurs as allotriomorphic crystals and in the shape of grains. This mineral is on the whole colourless. Only in a few instances faint pleochroism from very pale green to pale pink has been observed The large crystals show signs of alteration along cracks and margins, the products of alteration being a white opaque, and a dense earthy substance In the case of prismatic sections the alteration is more pronounced and consists partly of bastite and partly of a confused aggregate of serpentine scales and fibres. Minute plates and rods of iron oxide are found to be included in some crystals of enstatite. The larger crystals enclose a number of quartz grains. The hornblende which is of a pale green variety is faintly pleochroic and appears to be a secondary product derived from the pyroxene. In many cases it is seen on the margins of the pyroxene crystals and a gradual change from pyroxene to amphibole is clearly evident.

The quartz, felspar, and enstatite form a very fine-grained mosaic in which large grains and crystals of enstatite and quartz are set. The felspar is mostly triclinic. The biotite is of a highly pleochroic variety showing pale-yellow and red colours. The proportion of this mineral varies in different specimens Although not occurring so abundantly as enstatite it forms a large proportion of the rock in a few cases. Besides the black mica, sericite is

found to occur in this rock. It is an alteration product.

10 Sillimanite-garnet-biotite rock.

This rock occurs very close to the corundum bed It is a very hard and a very tough rock. It has a pinkish colour in hand specimens. It consists essentially of garnet, sillimanite, quartz, and biotite mica. The garnet appears of a very pale pink colour in thin sections and includes the other three minerals--biotite, quartz and sillimanite. In some cases the quartz, sillimanite, and biotite are arranged symmetrically in a peripheral fashion round crystals of garnet. Serpentine also occurs in the rock probably as an alteration product of sillimanite which occurs in the shape of platy aggregates, needles, and long slender prisms. The grouping of the slender prisms of sillimanite in a symmetrical fashion round garnet crystals is strongly suggestive of flow structure (Plate X, Figs 16 and 17).

11. Pyroxene felspar rock.

This interesting rock is exposed in a few places to the S.W. of the corundum band. It is dark in colour and its specific gravity is about 3·1. It consists essentially of a triclinic felspar and pyroxene, mostly diallage. The mineral next in importance to these two is biotite which together with the green, highly pleochroic hornblende present in the rock represent the alteration products of the pyroxene In sections of very fresh looking specimens of this rock olivine also has been observed. It has changed almost entirely to iron oxide in many cases. The diallage has altered in some cases to iron oxide and a mineral not unlike bastite, and in others to green hornblende and brown biotite-mica both of which are highly pleochroic. The alteration of the pyroxene to amphibole commences mostly on the marginal portions of the former mineral

FIG 20

Photo micrograph of garnet-biotite-sillimanite schist In the upper part of the figure crystals of sillimanite and biotite are seen to bend round the large crystal of garnet occupying the central part of the figure.

Polarized light. Magn. 40

FIG 21

Another section of garnet-biotite-sillimanite schist. As the photograph was taken between crossed nicols the crystals of garnet have come out dark while the long slender crystals of sillimanite appear white. Flow structure is well seen in this figure

Crossed nicols Magn. 40.

Photo. K. P. Sinor.

and gradually proceeds inwards Sections of the fresh rock show unmistakably a characteristic ophitic stiucture, the pyroxene enclosing lath shaped crystals of felspar (Plate XI, Fig 18). The felspar is on the whole clear and is characterised by many bent lamellae. It occurs mostly as lath shaped crystals which usually occur in clusters. In rocks which have undergone a certain amount of alteration, the felspar laths are characterised by ragged edges owing to the coarsely granular nature of the matrix consisting chiefly of pyroxene and secondary amphibole. The alteration of olivine to iron oxide proceeds from cracks in the crystal and from its margins until the whole of the crystal is gradually converted to iron oxide. During the alteration of olivine to iron oxide, silica and anthophyllite separate out, and in many cases form a zone round the original crystal resembling the chloritic zone surrounding crystals of pyrope. Iron oxide which is formed as the result of alteration of the olivine is found in a number of instances to be surrounded by a fibrous aggregate of highly pleochroic, brownish red mica and a greenish amphibole. Iddings in his 'Rock Minerals' mentions the occurrence of kelyphite-like shells of amphibole around crystals of olivine in certain gabbros in Sweden. The present case is more interesting in that the kelyphite-like zone contains mica also. From the above description it becomes quite evident that this rock is a gabbro. The rock which contains some unaltered olivine may be styled olivine gabbro. Various stages of alteration of this gabbro to a hornblende rock have been noted. During the initial stages the olivine begins to alter to iron oxide and probably also to amphibole. The alteration of the diallage starts along very fine lines in the crystal in the shape of minute rods and plates of iron

oxide, usually of a brown colour The pyroxene does not alter very easily. At first, the marginal portions only are affected and gradually the alteration proceeds inwards (Plate XI, Fig. 19). When the alteration has proceeded still farther the pyroxene breaks up into granules, many of these having changed to amphibole. In cases of complete alteration the whole of pyroxene has changed to hornblende, the rock consisting almost entirely of hornblende and plagioclose with a little biotite. It is quite probable that much of the hornblende rock at, and near, Pipra was formed as the result of metamorphism of an original pyroxene rock or gabbro.

12 Hornblende rock.

Hornblende rock occurs abundantly in, and around, Pipra. It occurs mostly in the shape of dykes and minor intrusions in the gneissose rocks. In hand specimens this rock is of a black colour and presents a massive, granular, or schistose appearance according to the arrangement of the constituent minerals All three varieties have been observed in the field Under the microscope thin sections of these rocks reveal the presence of minute irregular crystals, prisms, or fibres of hornblende which appear of a deep green or pale bluish-green colour. The pleochroism is intense in the case of the deeply coloured hornblende and changes from blue-green or greenish colour to a light yellow. Paler varieties are not so highly pleochroic. The mineral ranking next in importance in these rocks is felspar which is of the triclinic variety Some varieties contain abundant felspar while others contain a smaller amount of this mineral. Besides these two minerals, which form the main bulk of the hornblende rock in Pipra, others also occur. These are epidote, calcite, quartz, magnetite, rutile, and zircon. The epidote is characterized in thin sections by its high index of refraction which

FIG 22.

Photo-micrograph of pyroxene-felspar rock, showing the typical ophitic arrangement of pyroxene and felspar crystals The alteration of pyroxene is also clearly noticeable

Ordinary light. Magn 40.

FIG. 23

Another section of pyroxene-felspar rock In the top part of the photo-micrograph the pyroxene is seen to have changed to bastite, green amphibole, and brown biotite. The clear lath-shaped crystals are those of plagioclase felspar

Ordinary light Magn. 40

Photo K P Sinor

gives the crystals a high relief and also by its high birefringence which produces high order interference colours. It occurs in the shape of grains and minute crystals in small lenticular patches. The calcite, which is secondary, is the result of alteration of felspar The quartz occurs as small grains and as fine veinlets Rutile and zircon occur as minute grains. The micro-structure of these rocks shows in most cases a decided schistosity. However, instances of a crystalline pyroxenic rock altering to a hornblende rock have been noted which is suggestive of the fact that some at least of these rocks were formed as the result of alteration of originally igneous rocks by metamorphic agencies

13 Vein-rock resembling halleflinta.

About 200 yards to the N. of the corundum bed numerous stray pieces of a very hard and compact rock of a light to dark-grey colour occur. In hand specimens this rock shows no marked features except that it has superficially altered to a thin brownish crust and that it contains a few minute crystals of pyrites and calcite. This rock looks very much like a porcellanite. Even under the microscope thin sections of this compact rock resemble to a very large extent hornstones and porcellanic rocks. It breaks with a sub-conchoidal fracture. It presents, under the microscope, a microcrystalline to felsitic groundmass consisting mostly of quartz with some felspar and in which a few irregular grains of these two minerals and flakes of biotite are disseminated. The origin and true nature of this rock had puzzled the writer considerably and if it were not for the accidental finding of an interesting specimen, the true identity of this rock could not have been established. This specimen consists of a piece of fine-grained granitoid gneiss which is in inti-

7

mate contact with an exceedingly compact vein-rock (Plate XII, Fig. 20). This vein-rock resembles very closely the hard and compact rock resembling porcellanite and it is safe to assume that both have a similar origin If we take the granitoid gneiss to be the product of metamorphism of an originally sedimentary deposit the vein rock also would owe its origin to the same agency, viz. metamorphism. If, on the other hand, the gneiss had been formed as the result of metamorphism of an original plutonic rock the vein rock was most probably formed as a result of sudden cooling of the magma in one particular zone. Subsequent injection of the magma in the already formed gneissose rock would also account for the presence of this rock in close contact with the gneiss The fact that this rock had not been found *in situ* makes it rather difficult to state exactly how it was formed.

14. Brecciated rock resembling a porphyry.

In the same locality where stray fragments of the vein rock occur, pieces of a rock somewhat resembling a porphyry were found. Thin sections of this rock reveal under the microscope a fine-grained matrix in which fragmentary crystals and irregular grains of quartz and felspar occur. The ferromagnesian mineral consists of biotite which is present both in the ground mass and also occurs porphyritically as flakes and shreds. A few grains of garnet also occur. These appear of a pink colour in thin sections. The quartz which occurs in the form of irregular crystals and grains contains some very fine particles. These seem to have segregated at the margins of the crystals so much so that in some cases a thick border of these is visible. This finely granular matter was probably furnished by the grinding down of the crystals. There

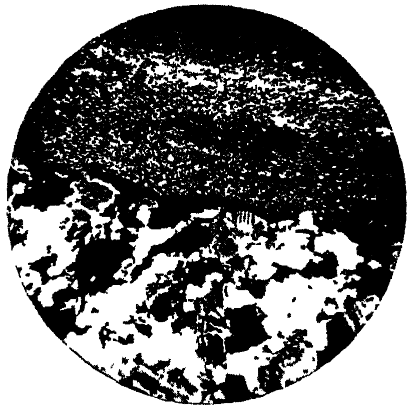

FIG. 24

Vein-rock resembling halleflinta. The photo micrograph shows the contact of the vein-rock with finely crystalline granitoid gneiss

Crossed nicols. Magn. 40.

FIG 25.

Brecciated rock showing the accumulation of very finely pulverised matter on the periphery of quartz grains

Ordinary light. Magn. 40.

Photo. K P. Sinor.

is also some brownish indefinable matter which has segregated in some parts more so than in others and it is also noticed that the minute particles mentioned above abound in those parts which contain a large amount of the brownish matter The segregation of the fine particles and of the brownish matter in certain parts gives a characteristic appearance to some of the sections of this rock (Plate XII, Fig 21). The felspar consists of orthoclase and microcline both and occurs partly as grains and small irregular crystals and partly as crystalline granular aggregates. The biotite which occurs in this rock is highly pleochroic changing from brownish red to a very dark red colour. Sections of this mineral which happen to be perpendicular to the basal plane give a very characteristic appearance under the microscope as the laminae have opened out along the cleavage lines. The lath shaped sections present a shredded aspect. This rock is undoubtedly a fine grained breccia and was probably formed as the result of crushing and grinding of an original gneissose rock along a fault plane upon which powerful movements must have occurred (Plate XIII, Fig. 22).

15 Metamorphic lime-stone.

About four miles from Pipra, near the village of Karaonti, bands of crystalline limestone are exposed in the bed of the Rehr River (Plate XIV, Fig. 23). The limestone contains serpentinous and micaceous layers and is also found to consist largely of tremolite. The maximum width of these bands amounts to about 30 feet. The central bands consist of dolomitic limestone having a saccharoidal texture. Those at the margins, which are not very far from the gneissic rocks consist of tremolite, enstatite, serpentine, and other minerals characteristic of contact metamorphism. Sections of the considerably

metamorphosed rocks showed calcite, enstatite, phlogopite, green mica, tremolite, serpentine, felspar, picotite, and green grossularite. The calcite shows the characteristic lustre mottling or twinkling when the lower nicol alone is rotated, due to a striking change of relief. Lamellar twinning is also frequently noticeable. The enstatite occurs as irregular crystals and is characterized by its low birefringence and straight extinction. When nearing extinction, sections of this mineral show a faint lamellar structure possibly due to intergrowth of some other pyroxene or due to its being composed of aggregates of prisms somewhat differently oriented. Inclusions also give it a characteristic appearance when nearing extinction. Phlogopite occurs largely in some parts of the limestone bands. Green mica has also been observed but it occurs sparingly. The tremolite consists of a number of long slender prisms aggregated together. It has a silky lustre and a pearly-grey colour. It occurs in intimate association with calcite. The serpentine appears in hand specimens of the crystalline limestone as dirty greenish-yellow grains and patches set in the calcareous matrix. It is the result of alteration of olivine. In many cases the alteration has advanced very far (Plate XIII, Fig. 24), but in a few cases unchanged kernels of olivine can be seen. Picotite and green grossularite occur in those parts of the rock which contain more of the silicate minerals and less of calcite. The former appears of a pale-brown colour in thin sections and the latter, a light green colour. Both being isotropic their sections remain dark between crossed nicols, even when rotated.

To sum up; Rewa corundum occurs in association with gneisses consisting mostly of quartz, orthoclase, microcline, and biotite on one hand, and on the other,

FIG. 26.

Brecciated rock resembling porphyry The shreds of biotite mica have come out black in the photograph.

Polarised light. Magn. 40.

FIG 28.

Photo-micrograph showing altered olivine in the metamorphic limestone exposed in the bed of the Rehr River near Karaonti. The figure clearly shows serpentinization of olivine.

Crossed nicols. Magn 40

Photo. K P Sinor.

with basic rocks such as pyroxene-granulite, gabbro, and hornblende schists. Schistose rocks containing sillimanite, andalusite, tourmaline, euphyllite, and rutile occur in very intimate association with the corundum bed. A schist consisting mostly of quartz and sillimanite with a little tourmaline and rutile largely occurs very close to the corundum bed Crystalline limestone occurs among the gneissose rocks of this district, but the nearest band of such limestone occurs at a distance of four miles from the corundum bearing ground and does not seem to be connected in any way with the formation of the corundum bed. The bed which has been described as "Jade bed associated with corundum" by Mr. Mallet does not contain any jade or jadeite whatsoever Careful study of a number of sections of the greenish coloured tough rock in close association with the corundum bed has not revealed any tremolite or jadeite but has proved the presence of sillimanite, andalusite, euphyllite, tourmaline, and rutile. It is the green chromiferous mica which gives the greenish tinge to the rock, while the toughness of the rock is due mostly to sillimanite. It may also be stated that tremolite does not occur in appreciably large amount in any of the rocks closely associated with the corundum bed at Pipra. It has been found to occur only in association with the crystalline limestone band in the bed of the Rehr River, south of Shahpur and north of Karaonti. The rock described by Mr. Mallet as "white tremolitic quartz schist breaking with a fibrous fracture" consists really of sillimanite and quartz with a little rutile and a few grains of tourmaline.

Summary of the various rocks and minerals associated with Rewa corundum.

XV. Estimate of the available Quantity of Corundum at Pipra.

From the geological map of the Pipra corundum field it will be seen that the corundum bed is about 700 yards long and about 80 yards wide. The bed, which is highly inclined, has an east to west strike which is also the strike of the country rocks Subordinate bands of gneiss occur within this bed. The eastern part of the outcrop is somewhat obscured by debris and towards the extreme west also, the bed does not show definite boundaries Regarding the persistence of the corundum in depth nothing could be said with certainty as no attempt to systematic mining has ever been made, the workings being restricted to the pebbles and boulders embedded in the surface soil.

In certain parts of the hill, the difference between the highest and lowest points amounts to more than 100 feet of which full 50 feet consists entirely of massive corundum. The lower part which is obscure, very likely, contains corundum as this mineral has been met with in some of the lower zones. Another difficulty in estimating the total quantity of available corundum is that the corundiferous bed is, in places, associated with schistose rocks. All these, introduce a great latitude in one's computation. However, if we consider the deposit to be 700 yards long and 80 yards wide, and if we suppose the average thickness to be 10 yards, there are 560,000 cubic yards of corundiferous ground. If we reject 90 per cent of this mineral as belonging to very impure corundum, and useless stuff consisting of gneissose rocks and schists consisting of sillimanite, euphyllite, tourmaline, and rutile, there remains 56,000 cubic yards of marketable corundum

FIG. 27.

Band of white crystalline limestone (marble) in the bed of the Rehr River near the village of Karaonti

Photo. K. P. Sinor.

the weight of which would be 168,000 tons approximately

This is a very modest estimate indeed, as it is more than likely that the corundiferous bed persists to a greater depth than that allowed for in the computation. Again, there is a fair amount of corundum in the surface soil to the south and west of the corundum bed which has not been taken into account. Although a large quantity of corundum in the shape of pebbles and boulders has been extracted in the past from the surface soil, a lot still remains. The above estimate of 168,000 tons, rough as it is, serves to show that the deposit is important and worth working and that it would last for at least fifty years, even if as large a quantity as 3,400 tons were exported annually therefrom.

XVI. Karkota Corundum.

About three miles to the W.S.W. of Pipra there is a small deposit of corundum, not far from the village of Karkota. This deposit had also been examined by the writer. It is quite insignificant in comparison with the main deposit at Pipra but its value lies in the suggestion which its occurrence offers of there being similar deposits of corundum in other parts of Singrauli It is quite likely that bands of corundum, smaller than the one at Pipra, occur in different parts of this district but owing to the thick jungle-clad nature of the country they have not yet been located. Comparison with other Indian deposits leads one to derive the same inference. According to Middlemiss the Paprappatti band of corundum in the Salem District, Madras, extends with some notable gaps a distance of nearly 40 miles, and that more than one parallel band of the corundum-bearing rock occur in that district.

This small deposit of corundum at Karkota had been worked in 1896 and 1897. How much corundum was exported is not known. The workings were restricted to the surface soil, and pebbles of corundum (called 'goti' by villagers) were extracted. Some specimens of the corundum bearing rock contained beautiful purplish corundum surrounded by green chromiferous mica (Plate IX, Fig. 15). Reddish corundum was also seen. In the Pipra deposit, sillimanite occurs abundantly and in close association with corundum, while at Karkota the corundum occurs with a large quantity of the green mica. The surface of the ground is too obscure to enable one to pronounce an opinion regarding the shape or dimensions of

the lenticle or vein containing corundum and associated minerals.

Stray pieces of corundum at Karkota and Beejpur.

A few small pieces of corundum and a number of small, water-worn pebbles of magnetite had been shown to the writer by one of the villagers of Karonti This village is situated due north of Pipra at a distance of about four miles Examination of the locality from which the fragments of corundum were obtained showed no signs of a corundum-bearing lenticle or pocket in the vicinity, nor was any corundum found in the alluvium. It is very likely that a few pieces of corundum had dropped there while it was being carried on pack-bullocks from Pipra to another place

Mallet has described in Vol. V, Part I, Records of the Geological Survey of India a similar occurrence of stray corundum which he found at Beejpur (Lat. 24° 2′ Long. 82° 53′) in Mirzapur, on the right bank of the river Rehr. He, too, failed to find a bed or lenticle of corundum in the gneiss of the neighbourhood or any traces of it in the alluvium. There were, in this case, not a few pieces but several lumps of corundum in one of the nallas in the alluvium. On mentioning these facts to an intelligent Zemindar of Beejpur he was told that some years ago a few bullock-loads of corundum from Pipra had been thrown away by some Brinjarries on account of more profitable employment for their bullocks or some other reason.

XVII. Industrial Applications of Corundum.

Owing to its great hardness, corundum has been used as an abrading agent since early ages. Even the Greek historians had a lot to say about the riches of the island of Naxos and its "smyris" (emery) which soon became known as an excellent abrading agent far surpassing sandstone in grinding power and hardness In the form in which corundum and emery were used in early times, viz. as grains and powder, the application of this mineral in the industries was of a very restricted nature. In the last century a process was invented by which the grains of corundum could be bound together in any desired shape with a suitable medium. Since that time the use of corundum as an abrading agent in metal-work has increased considerably and the demand for it has been so great that, of late, artificial abrading agents also have come largely into use.

Various forms of abrading agents.

Corundum is used as an abrasive material in the form of powder, grains, paper, cloth, sticks and slabs of various shapes and sizes, and grinding wheels, discs and cylinders

Preparation of emery.

The preparation of emery or corundum grains and powders of uniform grades is the first and most important thing in the manufacture of paper, cloth, wheels, and discs used as abrading agents. A short description of the methods employed in producing them will not, therefore, be considered out of place. If the corundum or emery is in the form of large blocks, they are crushed in large stone-breakers. The lumps from the large breakers

pass to smaller breakers and are further reduced in stamping mills or tube mills. The coarser grains are separated from the finer by an ingenious system of screens and sieves. The dust left by the crushing and screening process is then levigated in a series of vertical cylinders connected at the top by metal pipes A mixture of emery and water is introduced in the first cylinder of the series where it meets with an upward current of water introduced in the lower part of the cylinders which causes the lighter particles to float, only the coarse material sinking to the bottom. The finer material from the first cylinder passes over into the second cylinder where again some of the coarser stuff is deposited while the fine stuff is carried over into the next cylinder This process is repeated in the other cylinders and the material which reaches the last cylinder of the series consists of exceedingly fine particles of emery. These cylinders act on the principle of upward current separation which is also utilized in dressing ores, the contrivance being known as a spitzkasten. The finished raw material which consists of a series of grains of different fineness is classified and numbered according to the number of meshes per linear inch of the sieve through which it has passed. Grains of varying sizes from No. 6 to No. 220 are usually prepared by manufacturers of abrasives Grains too fine to size by ordinary sieving are graded by floating in water. F,FF, and FFF are symbols used to designate the different degrees of fineness from F (the next finest after 220) to FFF which contains the very finest dust and which takes a considerably long time to settle in water. This fine abrasive material is used by lapidaries and opticians for various purposes.

Emery paper and emery cloth were formerly made by hand but, at present, the various processes involved in their

manufacture are carried out by mechanical means by an ingenious device which evenly spreads a layer of emery powder or corundum grains of the requisite grade on sheets or rolls of paper or cloth strongly coated with glue on one side Emery paper and emery cloth are largely used in machine-shops for abrading and polishing metals and in tanneries for smoothing leather.

Emery paper and emery cloth

Corundum and emery wheels are usually made of corundum or emery powder bound together by means of shellac or rubber and then moulded to the required shape either by hand or in moulding machines The proportions of the binding medium and the emery or corundum grains are so regulated as to produce a tough and elastic structure The moulded discs are then subjected to pressures up to 3,500 tons in large hydraulic presses and then dried. When they have thoroughly dried they are turned down in lathes by means of black diamond (bortz) cutters.

Emery wheels and discs

Emery wheels of the early type were made of emery grains bound together by means of a substance which hardened like cement These wheels which were made by the cold process had many drawbacks, as cracks invariably appeared in them after they were in use for a short time and, finally, led to their rupture. Discs and wheels made with vulcanized rubber as a binding medium proved to be much better and possessed a high working efficiency. The increase in the price of rubber and the invention, in America, of a new binding material known as the ceramic medium acted adversely on the manufacture of emery wheels made with vulcanized rubber. There are various other forms of binding medium some of which are success-

fully used even at the present day. These consist of linseed oil, glue, sulphur, sodium silicate, and magnesium oxychloride each of which is used independently. The ceramic or vitrified discs and wheels have, however, proved to be the very best The binding medium is kaolin (China-clay) which is mixed with emery or corundum grains, moulded, pressed, and dried in an oven. The discs are then heated to a high temperature (white heat) in specially constructed kilns whereby the kaolin is vitrified with the abrasive. Reliability in work, excellent cutting power, unalterable texture, and insensitiveness to atmospheric influences are some of the advantages claimed for this type of wheel

Uses ot emery and corundum wheels

Emery and corundum wheels are largely used in the machine-shop for a variety of purposes. A number of contrivances have been invented in which emery and corundum wheels or wheels made of artificial abrading agents are made use of for the purpose of sharpening lathe tools, planing tools, chisels, drills, etc. Machines for sharpening paper cutters, cork cutters, leather splitting knives, circular saws for wood, and knives and blades used in many other industries have also been devised and, in these, corundum or emery wheels are used. Emery grinding machines are also used for grinding various castings into shape; for removing burrs and projections on castings; and also for grinding down shaftings, rollers, spindles, etc., to the requisite diameter. The circular grinding machine is one of the triumphs in the art of grinding. It has ousted the old lathe from its position as a finishing machine The vertical model has been found very useful for accurately grinding out cylindrical and conical bushes, bores, rings, and small motor cylinders.

Besides these, corundum, emery, and artificial abrasives have been put on the market in a number of forms for a variety of purposes. Knife sharpeners, instrument hones, razor hones, scythe-stones, axe-stones, files, strops, and valve-grinding compounds are all made of emery, corundum, or artificial abrasives mixed with other suitable materials.

XVIII. Possibilities of Development of the Rewa State Corundum Deposit.

No new industry can flourish in these days of keen competition unless a number of conditions which are most essential for the development of such an industry be present, and unless the most suitable methods of working be adopted Care and foresight are required before launching forth a new enterprize, and various factors on which the maintenance and smooth running of most industries largely depend have to be carefully taken into consideration. Proximity to a railway, cheap fuel, plentiful labour, ample supply of water, and a good climate are some of the chief requisites of most modern industries. We will now examine if the corundum deposit at Pipra in Rewa State possesses these advantages.

Means of transport.

It may be stated at the outset that the most essential requisite, viz. proximity to a railway is absent in the case of the Rewa corundum deposit. As stated before, this deposit is situated in the extreme east of Rewa territory, in Singrauli. It is 122 miles from Sutna on the E I. Railway as the crow flies, 118 miles from Umaria on the B.N. Railway, and 80 miles from Mirzapur on the E.I. Railway The actual distances are from 20 to 30 miles longer. No metalled road runs from Pipra to any of these three places, the only means of communication being the ordinary tracks which run from village to village and which follow the natural contours of the ground. The question which naturally arises is, "how has the corundum been sent to Mirzapur all these years?" Strange though it may sound, the reply is that corundum has been and is still

being sent on pack-cattle to Mirzapur from Pipra, a distance of more than 100 miles, about 30 miles of the road being in an execrable condition. This is one, if not the only reason, why large quantities have not been exported from Pipra in the past If this deposit was favourably situated with regard to a railway, its importance would have been very great indeed and specially during the period of the War, when the demand for corundum was very great, large quantities could have been sent away from Pipra. The production of corundum in the Khasi and Jaintia Hills amounted to 41,200 cwts. in 1917 and 37,920 cwts. in 1918 which shows that abnormal activity had prevailed there during those years. Mr. Mallet had stated in 1879 that the Khasi Hills corundum deposit was worth attention commercially. Its present activity has justified his statement The village of Nongryniew in Khasi Hills where corundum occurs is only within a day or two's journey from the Brahmaputra River for carts or laden animals; and herein lies the advantage of the Khasi deposits over the Pipra deposit, as the journey from Pipra to Mirzapur takes more than ten days.

Desirability of constructing a railway from Anuppur or Chandia on the B.N. Railway to Pipra in Singrauli.

The construction of a railway through the State territory is so intimately connected with the development of the mineral and other resources of the State that I consider it worth while to say a few words in this respect. The only railway which runs at present through Rewa territory is the Katni-Bilaspur branch line of the B.N. Railway which enters the State territory at Chandia and leaves it at Venkatnagar. It is owing to this railway that the Umaria Colliery has come into existence and because of this

railway the undeveloped coal-fields of the Johilla-Valley and Sohagpur will also spring into importance in the near future However, a very large part of the Sohagpur coal-field lies to the north of this railway and is inaccessible at present. A railway line from Anuppur to Beohari through Rampur, Belbahra, Jaintpur, Kaurpur, and Chitraon would pass through the Sohagpur coal-field from south to north. Besides this coal-field there is another known as the Singrauli coal-field part of which could be opened up by extending the proposed railway to Pipra from Beohari through Kachpech, Amgaon, Chandohar, Thal, Garwani, Karswa, Parari, Chitauli, and Amhari

An alternative route to Pipra

An alternative route from Chandia Ry. St. on the B.N. Railway to Pipra could also be suggested as one worthy of attention for a railway. This route

Anuppur	Lat.	23° 9′	Long.	81°47′
Beohari	,,	24° 1′	,,	81°26′
Rampur	,,	23°15′	,,	81°46′
Belbahra	,,	23°19′	,,	81°45′
Jaintpur	,,	23°30′	,,	81°48′
Kuarpur	,,	23°37′	,,	81°46′
Chitraon	,,	24°45′	,,	81°34′
Kachpech	,,	23°59′	,,	81°41′
Amgaon	,,	23°58′	,,	81°53′
Chandohar	,,	23°59′	,,	82° 0′
Thal	,,	23°56′	,,	82°17′
Garwani	,,	23°59′	,,	82°21′
Karswa	,,	23°59′	,,	82°29′
Parari	,,	23°56′	,,	82°32′
Chitauli	,,	23°53′	,,	82°36′
Amhari	,,	23°54′	,,	82°42′
Chandia	,,	23°39′	,,	80°47′
Pipra	,,	23°58′	,,	82°44′

would pass through Bharouli, Chilhari, Chansura, Jhalwar, Bawa, and Beohari. From Beohari to Pipra a route similar to the one mentioned above could be followed. A railway from Chandia to Pipra through Beohari would be the means of opening up the yellow ochre deposit at Bharouli. Besides, in the hill ranges between Bharouli and Batouraba iron ore occurs in several parts notably near Chilhari, and in many other adjoining parts in the transition rocks. This ore could be utilized when a favourable occasion arose. The advantage of connecting Pipra with Mirzapur is also evident enough.

Fuel.

Both in Rewa territory and in the adjoining parts in the Mirzapur District there are thick forests which could supply plenty of of firewood. Besides, there are some important outcrops of coal near the villages of Parari and Chitauli about fifteen miles to the west of Pipra ; also near Kachra and Dhari. The proposed railway routes from Anuppur and Chandia to Pipra pass close to these important coal outcrops. About ten miles to the N N W. of Pipra between Ghuraoli hill and Nownagar there is a bed of coal about eight feet thick. Six miles to the east of Nownagar near the village of Kota, in British territory, there are the remains of an old coal mine which used to supply coal for

Bharauli	.	Lat	23°55′ ·	Long.	80°55′
Chilhari	..	„	23°55′ :	„	81° 2
Chansura	..	„	23°56′ .	„	81° 5′
Jhalwar	..	„	23°57′ :	„	81° 7′
Bawa	..	„	24° 0′ :	„	81°15′
Beohari	..	„	24° 1′ :	„	81°26′
Ghuraoli	..	„	24° 6′ :	„	82°41′
Nownagar	..	„	24° 6′ .	„	82°90′
Kota	..	„	24° 6′ ·	„	82°44′

the Ganges steamers about the middle of the last century. This coal used to be carried to Mirzapur, a distance of about 100 miles over bad roads It is thus quite clear that a large supply of coal is available not very far from Pipra. The following is an analysis of a sample taken from the outcrop near the village of Parari :—

Moisture . . .	6·88
Volatile matter	29·52
Fixed carbon ..	46·50
Ash .	17 10
	100·00

The percentage of ash is rather high but it is likely that better coal occurs in depth.

Labour.

The tribes that reside in the forest area are Kôls, Gonds, Baigas, Bharia, Majhi, Panika, Baiswar, Biar, Agaria, Kotwar, Basor, Khairwar, and Pathari. Of these the Kôls, Baigas, Gonds, Bharia, Majhi, Agaria, Basor, and Khairwar are generally employed as labourers Of course, different tribes have different characteristics Some are more hardy by nature, while others are more deft with their hands. Some are skilful while others have an intelligence of a low order The rate of wages for males used to be 2 annas per day and that for females, 1 anna and 6 pies per day. The wages have now increased by more than 50 per cent due to an increase in the price of foodstuffs and the higher cost of living, in general. In the preliminary stages, labour would have to be recruited from near Pipra and inducements would have to be offered to them to entice them to take up their new vocation and cast aside their usual profession. The greatest difficulty is usually experienced at harvest time when a very large part of the population is busy cutting the crops and gathering the harvest and

it is then very difficult to induce them to do any other work. Nevertheless, if the prospects of a permanent employment be explained to them properly there would not be much trouble in recruiting their services.

Supply of water.

A plentiful supply of water could be depended upon at Pipra during any season of the year, from the Rehr River which runs close by. This river is about three quarters of a mile wide near Pipra. Of course, water would have to be pumped from the river into a large, specially erected, cistern from which the mines could be supplied with water regularly. A large and constant supply of water would be essential for concentrating the poorer varieties of corundum largely mixed with sillimanite and tourmaline

Climate.

The climate is very pleasant. The winter months are decidedly bracing, and even in summer the temperature is greatly modified by the abundance of trees and coppice and the proximity of the Rehr River

Importance of converting the corundum into grains and powder

Having discussed some of the factors on which the success of a commercial enterprize depend we will now take into consideration some other aspects regarding the development of the Rewa corundum deposit Six or seven years ago it would have been found quite remunerative to ship the best quality Rewa corundum to foreign ports from Bombay, but the altered conditions after the war have made the freights prohibitive and have greatly increased the shippers' charges, insurance fees, dock dues, etc. There is a fair demand for this mineral in its natural state in India but it is not large enough to induce anyone to take the risk of work-

ing the deposit on a large scale. There is, however, a large demand for it in the shape of grains as corundum powder or as corundum paper and cloth. The advantages of converting the corundum into grains or powder and coating these on cloth or paper are evident enough. The price of these commodities is more than six times the price of the mineral in the massive state so that the mineral in its powdered form or in the form of corundum cloth and corundum paper can bear transport well. Packing charges also would be considerably less. The greatest advantage, moreover, lies in the fact that there is at Pipra a fairly large proportion of the corundum which occurs intimately mixed with sillimanite, tourmaline, and other minerals which could also be utilized. No doubt, there is a large quantity of corundum which would only have to be crushed and then graded as described in a previous chapter but it would certainly be an advantage to treat the impure stuff also, because, in the process of extracting the mineral, both good and poor quality will be obtained. The good stuff could be sorted out by hand picking while the impure stuff would have to be crushed and then concentrated first on wilfley tables and then on vanners and buddles, in the same way as ores containing galena and zinc blende are treated.

Emery and corundum discs

As stated in a previous chapter, emery and corundum discs of various sizes and shapes are used for a number of operations in workshops and they have entirely replaced the sandstone grinders and steel files. They are, thus, the most useful products of corundum. Their manufacture requires a considerable amount of technical skill and would necessitate costly machinery. Different binding mediums have to be carefully selected for different

purposes as the successful operation of the discs depends in a large measure on the suitability of the medium employed. The discs after being moulded, pressed, and dried have to be turned in a lathe for which large size black diamonds (carbonados) are used This forms the most costly item of the whole equipment. For these reasons the manufacture of corundum discs is not advocated.

Corundum cloth and corundum paper.

Emery and corundum cloths and papers were formerly made by hand About fifty years ago a very ingenious machine had been devised by one of the managers of an emery factory in Hanover which has enabled all the necessary operations to be entirely performed by machinery. Rolls of paper or cloth are introduced in the machines, coated with glue on one side, and emery powder sprinkled on it uniformly. The paper or cloth is then dried in specially constructed driers and cut in sheets, when perfectly dry, by machines and then baled. The manufacture of corundum paper or cloth does not require so much skill as the manufacture of corundum discs and wheels and could profitably be undertaken side by side with the manufacture of corundum grains and powders of various grades.

XIX. A short description of other occurrences of common Corundum in India.

From the Quinquennial Review of the Mineral Production of India for the period 1909 to 1913 published by the Geological Survey of India in 1915 it appears that Mysore State produced the maximum amount of corundum in India during that period The production of the Madras Presidency fell short of this by a few cwts., while the output from the Pipra quarries in Rewa State amounted to one third of the total production of the Mysore State. While comparing these figures, however, it would be useful to bear in mind that the whole of the output of the Rewa State came from only one part, viz. the village of Pipra, while the production of the Madras Presidency and Mysore State referred to a number of Districts and Taluks. The average production of corundum from the Khasi and Jaintia Hills in Assam amounted to 280 cwts during the same period. Since 1916, however, the output of the Assam corundum has increased enormously and had reached the very high figure of 41,200 cwts. in 1917. From the point of view of large output, it is the most important corundum deposit in the whole of India, at present.

Mode of occurrence of corundum in Mysore.

Much of the corundum obtained in Mysore is reported to occur in the form of crystals and loose grains in the surface soil. Recently, the mineral has been found *in situ* in both decomposed and hard rocks which consist of veins of pegmatite or bands of syenite and granite traversing the older gneisses. It has been stated that the corundum is in many cases an original constituent of such veins or bands but at the same time it has been

pointed out that in the majority of cases the gneiss contains included bands and patches of basic Dharwar rocks such as hornblende and mica schists, hornblende and pyroxene granulites, pyroxenite and amphibolite and that the corundum bearing veins are frequently associated or in contact with such patches and often entirely enclosed within some of the larger ones. It is interesting to note this as Rewa corundum also occurs in association with pyroxene granulite and a garnetiferous sillimanite-biotite rock which is distinctly basic.

As Mysore corundum does not occur in the massive form but in the form of crystals embedded in hard rocks it becomes necessary to sort and select the mineral before it is despatched, even when it is found in the surface soil in the form of loose crystals, because, these naturally occur intimately associated with other hard minerals which have resisted decomposition due to the usual weathering agencies. The average cost of collection of the crystalline corundum was found to be Rs. 60 to 80 per ton, in 1916 The bulk of the output of Mysore corundum consists of loose crystals picked up in the surface soil while only a very small proportion is obtained from the soft decomposed rock by pounding it with wooden mallets and then separating the corundum by sieving and picking.

Varieties of Mysore corundum and their value

Mysore corundum varies in colour from ruby-red to various shades of pink, amethyst, brown, grey, green, and white. The ruby variety is the most in demand and it is stated that from Rs 300 to 500 per ton have, at times, been offered in Madras for good grades. The dull white to greenish variety is considered of little value as it is very much softer than the better varieties which fetch from Rs 100 to 250 in Madras.

Mode of occurrence of corundum in Madras.

Corundum occurs in the Madras Presidency in many places in the Trichinopoly, Koimbatore, Salem, and other districts. In the Trichinopoly area the corundum occurs, according to Sir Thomas Holland, as a primary constituent of basic rocks containing pyroxene and some form of spinel either hercynite, pleonaste, or ruby-spinel.

Occurrence of corundum in the Coimbatore District, Madras.

The occurrence of corundum in the Sivamalai Hills is very interesting as it forms a primary constituent of a coarse-grained felspar rock surrounding a series of lenticular masses of elæolite syenite. The felspar rock containing corundum (corundum syenite) and elæolite syenite are both considered to be contemporaneous in origin. According to Sir Thomas Holland, who has written a very interesting memoir on the Sivamalai Series of the Elæolitesyenites and Corundum-syenites of the Coimbatore District, the corundum has separated out as an original constituent from a magma supersaturated with alumina.

Corundum of the Salem District, Madras.

The corundum occurring in the Salem District in Madras Presidency has been shown by Middlemiss to occur in a series of lenticles consisting chiefly of orthoclase felspar disposed in parallel bands along the strike of a series of well-foliated pyroxene granulites traversed by veins of a coarse pegmatite. The band containing the lenticles, some of which have been found to measure 15 ft. in length, is said to have been traced for a distance of nearly 40 miles.

Other corundum localities

Corundum has also been found in four or five places in Bihar and Orissa. The occurrence in the Manbhum District near the

village of Salbanni (23°4′ : 86°20′) is interesting. According to Dr. Warth who made this discovery the corundum is of an exquisite deep-blue colour and is intergrown with colourless mica and blue crystals of kyanite, some of which are nine inches long. The corundum crystals occur usually as simple tapering prisms from half an inch to three inches in thickness.

Corundum has also been known to occur in the Khasi, and Jaintia Hills in Assam and at some places in Hyderabad, but details regarding their mode of occurrence are not known.

Increased output of corundum in Assam.

During the quinquennium 1909–1913, Assam had exported 1,400 cwts. of corundum The whole of this quantity had been produced in the year 1912. In 1917, the output had increased nearly 30 times, 41,200 cwts. having been produced in that year. In 1918, the quantity produced was 37,920 cwts. These figures are significant enough. The quantity of Rewa corundum exported from Pipra during 1917 amounted to 200 cwts. only, whereas in 1918 about 700 cwts. had been sent away from Pipra. From this it appears that the production of Assam corundum has increased by leaps and bounds within the last five years, and, at present, the corundum deposits of Assam rank first in the whole of India.

XX. Corundum Deposits of other parts of the World.

Canadian corundum deposits

Corundum deposits of the greatest economic value occur in Canada, the best known being those which lie in the eastern portion of the province of Ontario, on the northern shore of Lake Ontario These deposits occur in three different layers covering an area about 70 miles long by 2 miles in width in the districts of Haliburton and Hastings The rock which is being worked in the Hastings country is a syenite with 15 per cent of corundum.

Corundum deposits of the Ural District

In the Ural District corundum occurs as large lodes or beds in gneiss, granite, or syenite. In some cases the corundum is found in the form of large blue crystals up to 4 inches in length and about ½ inch across, in pegmatites containing orthoclase felspar. The syenites contain about 18 per cent of corundum while the pegmatites contain from 35 to 40 per cent.

Corundum occurrences in U.S.A

Corundum occurs in Massachusetts, at Chester, in association with magnetite, diaspore, ripidolite, and margarite, and is mined for use as emery. Bluish and green corundum occurs in New York, at Warwick, with spinel. At Newton, in New Jersey, blue crystals of corundum occur in granular limestone Corundum has been found at many points along a belt extending from Virginia across western North and South Carolina and Georgia to Dudleyville, Alabama. The locality at which most work has been done are the Culsagee mine, Corundum Hill, near Franklin. The corundum occurs in beds of chrysotile, serpen-

tine, and hornblendic gneiss. This mineral also occurs in some parts in Colorado and California.

South African corundum

In South Africa, the principal corundum producing districts, according to Hall, are situated in the Northern and Eastern Transvaal. A small amount of corundum is stated to come from Namaqualand. The mineral occurs in a felspar rock to which the name "plumasite" has been given. The felspar rock is intrusive in basic magnesian rocks and it is supposed by Hall that when the felspar reefs were intruded in the basic rocks a transfer of minerals took place due to interaction, silica being abstracted from the felspar rock by the basic rocks in consequence of which the felspar rock became supersaturated with alumina. The mineral is shipped in the form of loose crystals and also in the form of heavy lumps. During the war a great impetus was given to this industry, the production rapidly rising from 67 tons in 1915 to 755 tons in 1916, 628 tons in 1917, and 3,830 tons in 1918 In 1919, there was a considerable decline, the production amounting to 131 tons only. This was most likely due to a slump of corundum in the market owing to the decrease in the demand of this mineral after the War.

Madagascar corundum.

Madagascar is also a corundum producing country but the mode of occurrence of the corundum and other details are not known. The annual average for the five years from 1913 to 1917 was 930 tons, the maximum quantity having been produced in 1916 when the output was 1,680 tons.

Emery deposits.

Emery is the name given to an intimate mixture of opaque granular corundum, magnetite, hematite, quartz, and spinel. It is of

a dark brownish-grey to black colour and possesses great hardness and toughness. It very much resembles iron-ore with which it is often confused, and is also likely to be mistaken for chromite. Some American specimens of emery have been found to contain a large percentage of pleonaste. It is mostly very fine-grained, but specimens occur in which the corundum is in distinct crystals.

Smyrna emery

The most important emery deposit of the world at the present day is that of Smyrna, in the Province of Aidin, in Asia Minor. It occurs both in the massive state and in detrital form. Some of the lenticular masses attain a thickness of more than 200 feet Detrital emery forms, however, the main source of supply.

Naxos emery.

Emery also occurs at Naxos Island, one of the Cyclades, in the Grecian Archipelago, as irregular masses and lenticles in crystalline limestone. Some of the lenticles attain a thickness of about 160 feet. The monopoly of this important deposit was in the hands of a German firm for many years from 1871 This contract was not renewed by the Grecian Government on its expiry. From this time, the Asia Minor deposit sprung into importance, and even at the present day Smyrna is the largest producer of emery. About ten years ago, the production at Smyrna amounted to nearly 20,000 tons during one year, while during the same period Naxos had produced approximately 5,000 tons. At present, about 85 % of the world's supply is furnished by Asia Minor.

Other emery deposits

Emery occurs, also, at Chester, in Massachussets. The deposit extends for nearly five miles. The ore occurs in a vein which is about 12 feet thick in some parts and contains corundum ad-

mixed with varying proportions of magnetite. In New York State emery occurs at Peckshill The ore consists of pure emery and emery mixed with spinel and felspar.

Composition of emery.

Mineralogically, emery consists of corundum, magnetite, tourmaline, chloritoid, muscovite, margarite, spinel, rutile, and calcite. The following analysis of Kremno and Tenidi emery are by Tschermak :—

	Kremno Emery.	Tenidi Emery
SiO_2 . . .	5 64	5·45
B_2O_3	1·15	0·88
Al_2O_3	57·67	56 52
Fe_2O_3	33·36	34 65
MgO	0·83	0·43
CaO	0·43	0 90
Na_2O	traces	0·60
K_2O	0·31	0·40
TiO_2	traces	traces
Co_2	traces	traces
Loss on calcination ..	0·70	0·42
	100 09	100·25
Specific Gravity ..	3·72	3·98

Mineralogical Composition of Kremo and Tenidi Emery :—

	Kermno Emery.	Tenidi Emery
Corundum	52·4	50
Magnetite	32 1	33
Tourmaline	11·5	9
Chloritoid	—	—
Muscovite	2	3
Margarite	2	—
Calcite	—	1

The hardness and abrasive power of emery depend upon the amount of corundum present in the ore. In poor specimens the percentage of corundum is about 50, while some rich specimens from Chester, in Massachussets, contain about 84 per cent of corundum.

XXI. Artificial Abrasives.

Natural corundum and its variety—emery, have now to compete with various artificial products sufficiently hard to be used as abrasives A number of these artificial abrasives have been produced in the laboratory but the most serious competitors are carborundum, alundum, and aloxite.

Carborundum

Carborundum is a brittle, steel-grey, lustrous, crystalline compound consisting of carbon and silica. It is really a carbide of silicon corresponding to the formula SiC. It is manufactured by heating a mixture of silica and carbon (sand and coke) to a high temperature, in an electric furnace, when the following interaction takes place between silica and carbon:—

$$SiO_2 + 3C = SiC + 2CO.$$

It was Acheson who discovered this substance in 1891 while endeavouring to prepare from crystalline carbon a new abrasive material that would be harder than corundum. In his first experiments he used a mixture of carbon and clay, and subjected it to the heat of the electric arc. Later on, he found out that it was the silica of the clay which played a prominent part in the formation of the new substance.

In the works of the Carborundum Company, Niagara, the charge used in the electric furnaces consists of sand, coke, sawdust, and salt. The sand used is good glass sand containing 99·5 per cent of silica. The coke is of high uniform carbon content. The sawdust is used to render the mass porous, and the salt which is added in small quantities is to eliminate the impurities in the form of volatile

chlorides The furnaces used by the Carborundum Company measure 23 feet in length outside and have a capacity of 746 kilowatts The electrodes are composed of 25 carbon rods 33 inches long and 4 inches square, built into the end walls of the furnace. A furnace of the above size and capacity produces 3 tons of carborundum in 36 hours. The electric power consumed amounts to about 4 kilowatt-hours per pound of carborundum produced.

Physical properties of carborundum.

The specific gravity of carborundum varies between 3·171 and 3·214. Its specific gravity is, therefore, considerably lower than that of corundum. Adulteration of carborundum with emery may be detected by putting the sample in a solution of methyl iodide in benzol (having a specific gravity of 3·5) when the emery will sink in the liquid while the carborundum will float on it Crystals of carborundum belong to the rhombohedral system. Carborundum is harder than ruby and corundum Its position on Moh's scale of hardness is between 9 and 10, more near the latter. Carborundum being a refractory material is used as lining for metallurgical furnaces.

Aloxite and alundum

Aloxite and alundum are prepared from bauxite which consists of hydrated oxide of aluminium and impurities such as iron oxide, etc. The material which is used in the manufacture of these abrasives has to be as free as possible from any impurities, specially iron. The pure bauxite is first calcined and then raised to about 2,800°C when it fuses and is changed to crystalline corundum.

Aloxite and alundum are only different trade names given to one and the same product, viz. artificial corundum prepared from bauxite. Aloxite is the name given to the artificial corundum prepared by the Carborundum Co., Nia-

gara, and alundum is the name given to the same substance manufactured by the Norton Emery Wheel Co.

Corubin

Reference may here be made to another abrasive, prepared by a very interesting process which takes advantage of 'Goldschmidt Reaction,' and which is known as the "thermite" process In this process powdered aluminium is intimately mixed with chromium oxide in a suitable crucible, and the mixture is ignited by suitable means Once the ignition is started the combustion goes on uninterruptedly due to the intense heat generated owing to the extremely high combustion temperature of aluminium The resulting products consist of chromium and a hard substance to which the name corubin is given. This process is primarily used for the preparation of chromium; so, corubin may be looked upon as a by-product.

Production

The ever-increasing importance of artificial abrasives could be judged from the following figures. In 1894 and 1895 this industry was in its infancy, and the production of carborundum in those years amounted to 26 and 113 tons respectively. In 1900 the production was 1,201 tons, and in 1912 it reached the figure of 6,021 tons. Alundum appeared in the market in 1905 when 1,806 short tons were produced. In 1912 the production of alundum stood at 6,633 tons. The production of artificial corundum and carborundum in United States and Canada amounted to nearly 55,000 short tons in 1917.

XXII. Genesis of Corundum.

Views regarding the origin of corundum

Before discussing the origin of Rewa corundum, it would be best to describe the views generally held regarding the origin of corundum. In the forties and fifties of the last century several hypotheses relating to the differentiation of igneous rocks and molten magmas had been suggested to account for the genetic relationship and difference in the character of igneous rocks at one centre of eruptive activity, by Darwin, James Dana, Bunsen, Durocher, Von Cotta, and others; and in the latter part of the century by Teall, Rosenbusch and Brögger Light was thereby thrown as to the agencies or conditions most likely to influence the different parts of a mass of molten magma This principle of differentiation had not, however, been applied to explain the formation of various minerals from molten magma. In 1895, Lagorio had put forward the view regarding the pyrogenetic origin of corundum In 1897 T H Holland (now Sir Thomas Holland) had expressed his opinion that the corundum of Sivamalai Hills in Southern India had crystallized as one of the earliest formed minerals among the constituents of the elæolite syenite in which it occurs, in precisely the same manner as other simple oxides. Barlow also held the view that corundum was one of the first minerals to crystallize out from the molten magma. The researches of Vogt in connection with the magmatic segregation of ore bodies threw additional light on the subject of the origin of corundum.

Morozewicz's researches

The greatest outstanding work in this connection was undertaken and successfully performed by J. Morozewicz, who carried on a

series of experiments on the synthesis of rocks and minerals from 1891 to 1897, and succeeded in obtaining a number of minerals including corundum. From artificial magmas consisting chiefly of silica, alkalies, and alumina, he obtained corundum together with sillimanite, spinel, and cordierite, when alumina was used in excess According to whether the magma was rich or poor in MgO or FeO different minerals were formed Morozewicz's researches enabled him to arrive at a general law regulating the production of corundum and associated minerals The first and the most essential condition is that the alumino-silicate magma should be supersaturated, that is, it should contain an excess of Al_2O_3. If the magma be represented by the formula $RO(mAl_2O_3)\ n\ SiO_2$ where R denotes Ca, K_2 or Na_2, and n is equivalent to any number from 2 to 13, and $m > 1$ showing supersaturation, four different cases occur according to whether the magma is rich in FeO or MgO, or poor in these two oxides If the magma be poor in MgO and FeO, and if n, which is a measure of the silica content, be less than 6, corundum is formed. If n is greater than 6, sillimanite and corundum both are formed. If the magma be also rich in MgO or FeO, and if the silica content is less than 6, the excess of alumina goes to form spinel, or corundum and spinel both; and if n is greater than 6, then cordierite and other minerals are formed. For conciseness the above statements have been put in tabular form on the following page—

Supersaturated Alumino-silicate Magma.

$RO\ (mAl_2O_3)\ n\ SiO_2$

Where $R = Ca$, K_2 or Na and $n = 2 - 13$

Magma poor in MgO or FeO		Magma rich in MgO or FeO.	
When $n < 6$; Excess of alumina goes into corundum	When $n > 6$; Excess of alumina goes into sillimanite and corundum	When $n < 6$: Excess of alumina goes into spinel or corundum and spinel.	When $n > 6$ Excess of alumina goes into cordierite and other minerals

Morozewicz's researches thus conclusively proved that corundum could be formed as a pyrogenetic primary mineral by the separation of free alumina through differentiation of molten magma.

Occurrences of corundum deposits formed by the differentiation of molten magma

Corundum occurs in the Appalachian region of the United States and is, there, associated with rocks rich in magnesia and iron oxide and relatively poor in silica. The deposits are very frequent, specially, in North Carolina and Georgia which are situated in the above belt and where the country rock consists largely of peridotite. They also occur in Connecticut and Massachusetts. In the state of New York corundum occurs in association with norites. According to Pratt all these corundum deposits of the eastern United States which occur in association with basic rocks were formed by segregation. He takes it for granted that the peridotite magma contained an excess of alumina in solution.

The corundum deposits which occur in Ontario, Canada, are closely associated with rocks rich in alkalies, such as syenites and nepheline syenites. Barlow has successfully applied Morozewicz's principle regarding the formation of

corundum to the nepheline syenites of Ontario and has supplied chemical evidence as proof of the origin of Canadian deposits from molten magma. The rocks associated with the corundum deposits of the Ural District, also, consist of syenites The corundum occurring in the corundum syenites associated with the nepheline (elæolite) syenites in the Sivamalai hills in the Madras Presidency, India, has been proved by Holland to be primary and to have been formed from molten magma The corundum occurs not in the elæolite syenite but in the associated corundum syenite This peculiarity has been explained by Holland with the help of the Morozewicz law, thus. The felspar in the corundum syenite in which the corundum occurs corresponds very nearly to the general formula of albite or orthoclase ($R_2O. Al_2O_3\ 6SiO_2$). Now the minimum limit of saturation point for albite is 19·5 per cent according to Holland while for the elæolite syenite the minimum limit is 32·33. According to Morozewicz law, formation of corundum is not dependent on the basicity of the magma but on the ratio of the alumina to the sum of the other bases. From this it will be seen that in those cases in which corundum has been formed in nature as the result of differentiation of supersaturated alumino-silicate magma, Morozewicz's researches throw new light thereon, and his experimental work has, therefore, far-reaching effects

Metamorphic corundum deposit

So far, we have only considered the formation of corundum from a molten magma, by processes of segregation; and although large deposits of corundum occur in nature which have been formed in this way, still, there are other deposits which have clearly been formed in other ways. Such are the deposits of corundum which are found closely associated with the metamorphic rocks. Thus, the emery

deposits of the island of Naxos occur in crystalline limestone. The home of the Burma ruby, also, has been found in the crystalline limestone which occurs largely near Mogok The metamorphism of a highly aluminous deposit would also give rise to corundum. In the case of an argillaceous sediment, if the silica be in excess of the alumina, several other minerals such as sillimanite, andalusite, cyanite, and cordierite would be formed. Thus it is, that most of the corundum deposits formed by the metamorphosis of original sedimentary or crystalline rocks, having a large percentage of alumina, usually contain the above-named aluminium silicate minerals.

Corundum deposits formed by segregation, contact metamorphism, and pneumatolysis

Besides the cases described above, in which segregation and metamorphism play a prominent rôle, there are others in which more than one process were responsible for the formation of corundum Such are the Transvaal corundum deposits which have been shown by Hall to owe their origin to magmatic segregation, contact metamorphism, and pneumatolysis, the three agencies acting in stages According to him, the corundum felspar (plumasite) reefs originated as pegmatitic derivatives of a granitic magma. In this process, magmatic segregation must have played the chief part During the second stage when the reefs were intruded in basic magnesian rocks they become supersatured with alumina which caused the excess to separate out as corundum while felspar was left over. This was the contact metamorphic stage Subsequent magmatic changes, possibly under pneumatolytic conditions, changed the corundum felspar reef into a margarite felspar body to which the name marundite is given. This ingenious hypothesis advanced by Hall clearly shows that during the formation

of some ores and minerals many agencies have acted simultaneously or in cycles and that more processes than one are responsible for their production.

Origin of Rewa Corundum.

Previous views regarding the origin of Rewa corundum

In Part I of the Economic Geology of India, in which Holland has described the different occurrences of corundum in India, Rewa corundum has been placed among the group of corundum occurrences with basic associates. He states, "Not far from the corundum deposit there occur bands of crystalline limestone and dolomite with serpentine. Until the exact petrographical relations of these beds to the corundum have been made out, the Rewa corundum may be retained in the group of corundum occurrences with basic associates." These remarks, it may be said, were not based on Holland's personal observations but on Mallet's description of this deposit As has been stated before, Mallet's description agrees, in the main, with the writer's observations with two or three exceptions which it would be well to point out. The rock which occurs in what he has termed "Jade bed" really consists of sillimanite, andalusite, chromiferous mica, tourmaline, and rutile. In another place he mentions the jade as having been derived from hornblende rock. The writer has not seen any jade or jadeite in the rocks associated with the corundum bed nor has he marked the passage of the hornblende rock into jade. Secondly, the rocks which have been described by Mallet as tremolitic quartz schists, consist really of sillimanite and quartz, and should be called quartz-sillimanite-schists In the Economic Geology of India it is also mentioned that Prof Judd had found picotite (chrome spinel) in Rewa corundum The micro-

scopic examination by the writer, of a number of sections of the different varieties of corundum and associated rocks, has not revealed the presence of picotite in any of them It is, therefore, natural to conclude that this mineral, if it is present in the corundum bed, occurs very sparingly. It is essential to emphasize this fact, as, the presence of a fair amount of spinel would point to the derivation of the corundum from a magma rich in MgO and FeO according to Morozewicz law. It should also be made quite clear that although basic pyroxenic rocks do occur in the vicinity of the corundum bed, corundum does not occur in any of these nor do these rocks envelope the bed, showing that this mineral was not formed as the result of the differentiation of a basic magma. Besides, the basic intrusions are not large enough to account for the occurrence of the corundum as will be seen from the geological map of the Pipra corundum-field. Although pyroxene-felspar rocks, hornblende rocks, and pyroxene granulites occur close to the corundum bed there seems to be no genetic relationship between these and corundum

Gneissose rocks associated with the corundum bed

We will now consider whether there is any relationship between the gneissose rocks which form the main bulk of the rocks in this area and the bed of corundum which to all appearance lies within them These gneissic rocks extend for miles in different directions There is no doubt that their present texture and mineral composition is the result of regional metamorphism. There is no criterion, however, by which one could definitely say whether these rocks were originally sedimentary rocks which have been wholly metamorphosed or whether they were originally eruptive rocks which have acquired the foliation and other characteristics peculiar to gneisses. In the

case of the Sivamalai series of rocks in Southern India, in which corundum is found in intimate association with certain syenites, the presence of elæolite is shown by Holland to be suggestive of their igneous origin, but in the area under discussion, there is no such mineral which is peculiar to igneous rocks only, and which has not been found among sedimentary rocks; nor are the phenomena of contemporaneous vein formation and of the occurrence of basic fine grained xenoliths which are common to igneous rocks markedly developed or prominent in the gneissose rocks of this part The more or less parallel disposition of the several beds of gneissic rocks, hornblende schists, and crystalline limestones is to a certain extent suggestive of their formation from original sedimentary rocks but it may be stated that the intrusion of sheets or sills of molten igneous matter would also produce the parallel banding of rocks, which in the case of igneous rocks is known as sill structure

Metamorphic origin of Rewa corundum

The question whether the gneissose rocks of Pipra were igneous or sedimentary in origin does not, however, affect the present case. Certain it is that regional metamorphism had acted on the original rocks, whether igneous or sedimentary, and had imparted to them special mineral and structural peculiarities. The lenticular texture and fluidal structure of many of these rocks, and the folding and contortions produced in some of the schistose rocks (see Plate XV, Fig. 25) clearly point to metamorphic agencies. Moreover, the typical aluminium silicate minerals sillimanite, andalusite, biotite, fuchsite, and garnet which occur in the zone enveloping the corundum bed clearly point to the fact that the bed consisted originally of a highly aluminous deposit, which had subse-

FIG 29

Photograph showing folds, wrinkles, and contortions produced in schistose rock as the result of metamorphism.

Locality Rehr River near Karaonti.

Photo K P Sinor

quently undergone metamorphism. It is easy to suppose that this deposit contained a high alumina content in the central part and that towards its margins it gradually merged into an argillaceous rock containing an excess of silica over alumina. When such a deposit was subjected to heat and pressure, the central highly aluminous part was converted to corundum while the marginal portion was transformed into schistose rocks consisting mainly of the aluminium silicates named above. In intimate association with the corundiferous bed, there is an interesting rock consisting of sillimanite, biotite, quartz, and garnet which very much resembles a rock occurring at Clova in Forfarshire described by Harker. This rock which was originally a grit had been metamorphosed to a garnet sillimanite rock. The occurrence of the garnet sillimanite rock of Pipra is suggestive of the fact that the argillaceous deposit which had been metamorphosed partly to corundum and partly to aluminium silicates must originally have contained some siliceous bands which were later transformed by metamorphic agencies to their present state This rock has been described in detail in a previous chapter.

Origin of the crystalline limestone bands.

The formation of the limestone bands near Saipur, Ekpie, Perarwa, Manjoli and Bichi Nuddee is to be ascribed to the metamorphism of highly calcareous sediments. Those parts of the original rock which contained calcium and magnesium carbonates without admixture of silica or ferromagnesian minerals crystallized out as calcite or dolomite, while the marginal parts of this rock which merged into others containing ferro-magnesian minerals and silica were changed to tremolite, mica, serpentine, and pyroxene bearing rocks.

PART III

LIMESTONES, IRON ORES, OCHRES, FIRE-CLAY, ETC., ETC.

PART III.

LIMESTONES, IRON ORES, OCHRES, FIRE-CLAY, ETC., ETC.

XXIII. Limestones of Rewa State.

Limestone occurs in Rewa State in several places. The different deposits vary in character and mode of occurrence. In Rewa State they have been found to occur in the following geological formations:—

1. In surface soil and alluvium as Kankar and Tufa.
2. In Lameta rocks, which underlie the traps, beds of calcareous grit and crystalline limestone are met with in Rewa State.
3. In the Lower Bhander division of the Upper Vindhyan series massive limestone occurs in thick beds overlying the Ganugarh shales and Upper Rewa Sandstone, and underlying the Bhander Sandstone and Sirboo Shales.
4. In the Rhotas and Khemjua groups of the Lower Vindhyan rocks beds of massive limestone occur in many parts of the Rewa State.
5. In the old crystalline formations consisting of gneisses and schists beds of crystalline limestone occur. This limestone is usually somewhat dolomitic.

We shall deal with each one of these in detail.

Kankar

Kankar is a concretionary form of calcium carbonate which is mostly derived from the weathering of gneisses, schists, and

traps containing silicates of lime. Its chief home is in the older alluvium Its occurrence in the surface soil is widespread in many parts of India. Although lime kankar occurs in many parts of the Rewa State, large nodules and lumps have not been found. It is used for lime burning on a small scale in several places. When the Umaria coal-field was first opened out the kankar which occurs near Khalesar (23° 31′ : 80° 54′) was used for lime burning. The following is an analysis of Khalesar kankar —

Silica	20·10
Alumina and Iron oxide	4·95
Calcium carbonate	71 40
Magnesium carbonate	3·55

As there is plenty of calcareous material near Umaria for lime burning, both in the Lameta beds near Karkelly and in the crystalline formations near Majgawan, it is unlikely that kankar will be largely used. It may also be stated that the deposits of kankar in Rewa State are not of much economic importance due to the small size of the concretions.

Tufa

Tufa is the name given to the porous material deposited by calcareous springs. The writer has come across only one deposit of tufa or travertine in Rewa State. The locality where it occurs is about 4 miles to the S.W. of Umaria in the neighbourhood of Karimati (23° 29′ : 80° 52′) and Aganhuri (23° 28′ . 80° 53′). This deposit which occurs in the supra-Barakar formations had, clearly, been formed by waters highly charged with calcium carbonate which abounds in the Lameta beds which form a fringe round the Dandia Hill. The following is an analysis of the Karimati tufa :—

Silica	1·65
Alumina and Iron oxide ..	1·05
Calcium carbonate	95·20
Magnesium carbonate	2·10

Lameta Limestone

In Southern Rewa, beds belonging to the Lameta group have a wide distribution They extend from near Umaria on the Katni Bilaspur branch line of the B N. Railway to Amarkantak, a distance of more than 80 miles They occur in close association with the overlying traps, and usually form a fringe around them. The Lameta group consists of limestones, sandstones, and clays. The rock which abounds in this formation in Rewa State is a gritty form of limestone in which clear crystals of calcite are found to be frequently developed In some parts, as near Amarkantak, the Lameta rocks resemble more a calcareous grit than a limestone On the other hand, there are certain localities where pure crystalline limestone occurs in the Lametas, as for instance, in the Patparia Nadi to the west of Kotipat Pass (23° 17′ 81° 9′) which is at a distance of about 8 miles from Ghunguti railway station on the B N. Railway. Although the extent of this formation is very great, accessible localities are unfortunately very few. The exposures to the south and south-west of Karkeli and to the south and south-west of Ghunghuti are nearer to the railway line than others. The exposure nearest to Karkeli is about 4 miles distant while that near Ghunghuti is at a distance of about a mile from the railway.

Analysis of an average sample of Lameta Limestone:—

Carbonate of Lime	61 65
equal to CaO 34 53%	
Carbonate of Magnesia	6 38
equal to Magnesia 3 04%	
Oxides of Iron and Alumina	1·56
Siliceous matter. (Insoluble)	30·01
Loss	0 40
	100·00

The above was analysed by Messrs. R. V. Briggs & Co., Calcutta.

Lower Bhander Limestone.

The most important deposit of limestone is that which occurs in the Lower Bhander group of the Upper Vindhyan series. The limestone beds cover about 370 square miles. The most southerly exposures of the Lower Bhander limestone occur about 6 miles due east of Uchera railway station on the E.I. Ry. The principal exposure is near the village of Charhauta (24° 23′ : 60° 58′) on the Bakaoli Nadi. The next in importance is near Bakhura. There are two smaller exposures near Punri and Bhatgama on both sides of the Bakaoli Nadi. The exposure near Punri is nearest to the railway station, being 4½ miles distant therefrom. The exposure near Charhauta is about two miles long and from ¼ to ½ a mile in width. There are also a few inliers about 6 miles to the east of Maihar. These, however, lie outside the State boundary The limestone exposure becomes wider near Amarpatan (23° 19′ : 81° 2′). It then follows a north-easterly course and is continuous right up to Rewa and from there to within a mile of Raipoor (24° 34′ : 81° 28′) which forms the eastern extremity of the outcrop of Bhander limestone. From Raipoor it could be traced back for about 40 miles in a westerly direction, the most westerly exposure being

near Ahirgama, $6\frac{1}{2}$ miles to the north-west of Sutna railway station. The exposed area of the Bhander limestone has a roughly fork-shaped form having its apex at Raipoor. The arm to the N.W. of Raipoor has a length of 40 miles while the south-western arm has a length of about 24 miles.

The following shows the general succession of beds near Sutna, Rewa, Amarpatan, and adjoining parts:—

Bhander or Bundair	Upper Bhander Sandstone	Upper Vindhyan
	Sirboo Shales	
	Lower Bhander Sandstone	
	Bhander Limestone	
	Ganugarh Shales	
Rewa	Upper Rewa Sandstone	
	Lower Rewa Sandstone	
Kaimur	Upper Kaimur Sandstone	
	Lower Kaimur Sandstone	

Many of these beds could be seen between Rewa and Ramgurh and between Ramgurh and Ramnagar.

Limestone Quarries and Lime Works of the Sutna Stone and Lime Company, Ltd.

The Bhander limestone is worked on a large scale by the Sutna Stone and Lime Company, Ltd., near Lalgaon (Lalpur) about $4\frac{1}{2}$ miles to the N.N.E. of Sutna Railway Station on the E.I. Ry. The lime works are situated about a mile to the south-east of Lalgaon. Most of the quarries are situated to the north and north-east of the lime kilns. Limestone outcrops in many places not far from the works. There is, therefore, no overburden to be removed. The different beds vary in composition. Some are siliceous while others contain from 90 to 95 per cent of carbonate of lime. The depth of most of the quarries is less than 15 feet. The following three analyses are of samples of the best quality limestone obtained from three of the principal quarries:—

	Sample No 1	Sample No. 2.	Sample No. 3
Silica	3 92	5·63	6·25
Alumina and Iron oxide ..	1·05	1·18	1 10
Carbonate of lime ..	94 08	92·21	90 62
Carbonate of magnesia ..	0·81	0 95	1 86

As stated before, the different limestone bands differ in character and composition and care has, therefore, to be exercised in selecting suitable material for use as flux in the smelting of iron ores. It may be stated, however, that there is a very large quantity of good limestone close to the surface which is a very great advantage, as the working cost is thereby considerably reduced than if the limestone had to be worked at great depths. The following table shows the production of limestone, lime, and stone-setts at Sutna Stone and Lime Co.'s works at Lalgaon near Sutna, in 1920, and the estimated value thereof :—

Production of Limestone, Lime, and Stone Setts at Lalgaon near Sutna in 1920.

	Output in tons	Estimated value	Average No of Labourers.
		Rs.	
Unslaked Lime ..	24,809	4,05,221	1,935 Men.
Slaked Lime ..	4,562	21,116	876 Women.
Refuse Lime ..	763	1,038	203 Children
Stone	53,089	79,633	———
Stone Setts .. .. (pieces).	95,977 pieces.	11,517	3,008 Average number employed daily at the mine in 1920.

FIG. 30

Photograph showing a few of the lime-kilns belonging to the Sutna Stone & Lime Co , Ltd., Sutna

Photo. *K. P. Sinor*

The table given at the end of this chapter shows the despatches of limestone, unslaked lime, slaked lime, and refuse lime from Sutna siding by the Sutna Stone and Lime Co., Ltd., from 1910 to 1920 and the royalty realized thereon by the Rewa Durbar. The capital invested in the lime works by the above company is Rs. 1,15,200 Much of the limestone is annually railed a distance of about 530 miles to the Barakar Iron Works where it is used as a flux for iron ores in the blast furnaces. Some of the limestone is sent every year to the Katni Cement and Industrial Works where it is used in the manufacture of cement

Occurrences of Lower Vindhyan Limestone in Rewa State.

Lower Vindhyan limestone is largely quarried at Katni and Jukehi in the Central Provinces and is utilized for lime burning and in the manufacture of cement. The limestone band which occurs near Katni and Jukehi runs almost parallel to the East Indian Railway line as far as Bhadanpura, then takes a more easterly course and enters Rewa territory two miles to the S.W of Intwa (24° 11′ : 81° 1′) and runs by south of Nando, Mirgaoti, and Ramnagar to near Rampur. This band is continuous for about 85 miles from Jukehi to Rampur and runs for nearly 35 miles in Rewa territory. There is another band which runs parallel to the above band from Sulkma in Rewa territory to Rampur and thence continues as far as Koludi through Kua, Churhat, and Lakhaora, a distance of about 64 miles. There is a third band which commences at the confluence of the Mahanadi with the Sone River near Sukwari and is traceable for 20 miles up to Ucheyra. This band also runs parallel to the two bands mentioned above. There are other small bands and stray outcrops of limestones to

the south of the Sukwari-Ucheyra band. The largest of these exposures is that near Bara Ujara which crosses the Sone in an east to west direction

Of the three main bands the most northerly which commences south of Intwa contains pure limestone The second band which begins at Sulkma and which extends right up to Koludi is very impure. The third band which commences near Sukwari is purer than the Sulkma-Koludi band but is not quite so pure as the first. All the three bands and the stray outcrops belong to the Kheinjua division of the Lower Vindhyan formations.

Rhotas Limestone.

There is another stage or division in the Lower Vindhyans in which limestone occurs extensively. This is the Rhotas Stage which is the uppermost division of the Lower Vindhyans. It underlies the Kaimur sandstones This formation is very persistent and extends from the western extremity of the Rewa boundary near Intwa right up to the eastern boundary of the Rewa State near Burwadee, that is, from Long. 81° 0′ to Long. 82° 50′ It runs practically in an east to west direction on the southern side of the Kaimur scarp, all along the foot of the hills The formation is largely covered by alluvium in many parts The Rhotas limestone has been used in the construction of the Chhuia Ghāt, for that particular section of the pass which lies near the escarpment side.

Limestone in the Basal Stage of the Lower Vindhyan.

Besides the Kheinjua and Rhotas limestones described above there occurs in Rewa territory a limestone formation belonging to the Basal Beds of the Lower Vindhyan. There is one such Basal limestone band ½ mile to the S.E. of Deora which is about 8 miles long and runs more or less parallel to the Kheinjua

limestone bands. East of longitude 82° 25′ there are a few outcrops of Basal limestone just south of the Sone River. This band runs very likely as far as Jathora near the Rewa State boundary. A large part of this formation is covered by thick alluvium from near Khattai to the Rewa boundary.

The succession of the main groups of the Lower Vindhyan is as follows :—

Rhotas Stage.
Kheinjua Group
Porcellanites and Trappoids.
Basal-beds.

Of these four groups the first two contain an inexhaustible supply of limestone but, unfortunately, owing to the great distance of the exposures of these limestone beds from a railway, the deposits are practically of no value at the present time.

Beds of crystalline limestone occurring in metamorphic rocks.

Beds of crystalline limestone occur in the gneisses of Rewa territory as also in the Bijawars. In Northern Rewa beds of crystalline limestone occur in the gneiss of Singrauli. The following are the principal localities :—

1. In the bed of the Rehr River near Karaonti (24° 2′ 82° 44′)
2. South of Ekpie (23° 56′ · 82° 43′).
3. Between Amhara (23° 55′ . 82° 39′) and Karami (23° 55′ : 82° 38′).
4. Between Mainadhye (23° 58′ : 82° 38′) and Perarwa (23° 56′ : 82° 38′).
5. In the gneiss inliers near Koelkut (23° 57′ : 82° 32′) and Ukraval (23° 57′ : 82° 35′).
6. ½ mile to the north-east of Parari (24° 11′ : 82° 34′).

The most noteworthy is the band in the bed of the Rehr River It is about 30 feet thick This marble has a beautiful white colour and saccharoidal texture. This bed is intimately associated, near its margins, with serpentinous layers and a rock consisting of tremolite, enstatite, picotite, green grossularite, felspar, and calcite

The other beds mentioned above consist of white, greenish white, or greyish crystalline limestones. They are all associated with more or less serpentine and contain varying amounts of magnesian carbonate.

In Southern Rewa, bluish white marble occurs at Majgawan 4 miles to the N W. of Umaria It contains about 18 per cent of magnesium carbonate Crystalline limestones very similar in appearance to the Majgawan marble occur in the Bijawar formations at Karud (23° 29′ : 80° 39′), Amdari (23° 28′ · 80° 39′) and Jhapi (23° 27′ : 80° 38′) about 18 miles to the west of Umaria

Many of the above mentioned crystalline limestones are good enough to be employed for structural purposes Although much inferior to the celebrated Makrana marble of India and the beautiful foreign marbles imported from abroad they could very well be utilised for flooring and for decorative purposes in large edifices.

In the following table analyses of some of the crystalline limestones are given .—

	A	B	C.	D.
	Karami Crys Limestone	Perarwa (sub-band)	Ekpie.	Perarwa (main-band)
Calcium Carbonate ..	83·12	85 92	67 28	64·68
Magnesium Carbonate ..	7·04	8 19	30 24	34·14
Iron Carbonate ..	1 28	0 76	0·78	0·58
Insoluble . ..	10 16	5 52	0 50	0·76
	101 60	100 39	98 80	100·16

A is a fine grained dark-grey crystalline limestone which occurs to the east of Karami *B* is a greenish-white fine-grained crystalline rock which occurs as a subordinate bed in the dolomite *D*. *C* is a white dolomite with a saccharoidal texture.

POSSIBILITIES OF THE FURTHER UTILIZATION OF THE LIMESTONE DEPOSITS OF REWA STATE.

Having described the various deposits of limestone which occur in Rewa State we shall now see if there is any likelihood of further development of the extensive deposits of Bhander limestone. As stated before, these deposits cover nearly 370 square miles of which only the strip north of Sutna Railway Station is, at present, worked In Rewa, limestone is quarried on a small scale, though, since the last two or three years more activity is manifest there, than before. The limestone quarried at Rewa is used only locally. If there was a railway from Sutna to Rewa and from Rewa to Govindgurh (24° 22′ : 81° 20′) the limestones of Rewa and the sandstones near Govindgurh would both find a ready market.

Prospects of manufacture of Portland Cement in Rewa State

Before closing this chapter on limestones it would be well worth to describe the prospects of manufacturing Portland Cement from the limestones of Rewa State. It is, indeed, surprising that no attempt has hitherto been made in this direction by any enterprising firm During the last decade many concerns for the manufacture of Portland Cement have come into existence and they are all in a more or less flourishing condition. Rewa State possesses the raw materials necessary for the production of cement Fuel for generating power and for the kilns could be had cheaply from the coal-fields of Rewa State. Labour is plentiful. There is, therefore, no reason why an enterprise for the manufacture of cement in Rewa State would not succeed On the contrary, there is every reason for optimism in this direction We shall now examine the matter in detail.

Raw materials for cement manufacture

For the manufacture of cement the raw materials required are suitable limestones and clay or shales The limestone which outcrops near Lalgaon, Bathia, and other places to the north and north-east of Sutna consist mostly, as stated before, of calcium carbonate, its percentage varying between 85 and 95 The quantity of magnesium carbonate, on the other hand, is very low, ranging from 0·5 to 2 0 per cent. The high content of calcium and the low content of magnesium are both in favour of the Sutna limestone. The presence of 3 to 4 per cent of magnesia in Portland Cement is considered to be detrimental and, therefore, limestone used in the manufacture of cement should be as free from magnesia as possible. The other ingredient required in the manufacture of cement is clay There are two sources for this material not far from

Sutna. One of these consists of shaly beds overlying the Bhander limestone while the other consists of an alluvial deposit on both sides of the Sutna River Although no experiments have been made with either the shales or clays the writer feels sure that suitable material will be found in one or other of these formations.

Suitable site for Cement Works

A very suitable site for the erection of cement works in the writer's opinion is one between the villages of Daowari (24° 33′: 80° 51′) and Dilaora (24° 32′ : 80° 53′) south of Sutna Railway Station The chief advantages of this site are proximity to the railway and a plentiful supply of water The limestone beds are also within an easy distance from the suggested site and the clay deposits are quite near. The writer would have suggested a site to the north of the railway station in the neighbourhood of the limestone outcrops but there is a great scarcity of water in this part The Sutna Stone and Lime Co., Ltd., are experiencing great trouble on this score as many of their wells dry up in the hot season. The site near Daowari and Dilaora has the advantage of being quite close to the Sutna River from which a copious supply of water could be depended upon during any season of the year. This river has not been known to run dry even in the summer months.

Cheap fuel

Regarding coal for generating power it may be stated that it would be quite possible to make arrangements with the Rewa State Collieries at Umaria for large annual supplies at a cheap rate. The average calorific value of Umaria coal is about 5,500 calories Although Bengal coal has a somewhat greater heating power not only would its initial cost be greater but the freight charges also would be higher than for Umaria coal which would have to be railed a

distance of 100 miles only. The Bengal coal would have to be railed a distance of at least 450 miles.

A SHORT DESCRIPTION OF THE PROCESS OF CEMENT MANUFACTURE.

For those interested in the manufacture of cement a short description of the process of manufacture is given below.

Portland Cement is cement made by intimately mixing limestone in definite proportions with a suitable clay, grinding it to an impalpable powder, and calcining the homogeneous mixture so formed to incipient fusion. The greatest care is required to so proportion the clay and limestone that complete chemical union takes place between the aluminium silicate of the clay and calcium oxide of the limestone when the mixture is calcined. Two processes are used in the manufacture of cement —the wet process and the dry process. The wet process is used for soft and hard limestones, both. In this process the clay is first mixed with water and reduced to a thin slurry in an ordinary washmill. The limestone is broken into small lumps by means of jaw-breakers whence it is conveyed to ball-mills which pulverize the stone. It is then reduced to an impalpable powder in tube-mills. While the limestone is being ground in the ball-mill the thin slurry formed by mixing clay and water is allowed to enter it and more water is added to make the mixture flow easily The slurry which issues from the tube mills must be fine enough to pass through a sieve with 200 meshes to the linear inch (40,000 meshes to the square inch). The residue on the sieve must be less than 8 per cent. The slurry is then conducted to specially constructed tanks where it is thoroughly stirred up.

Samples of the mixture are then tested and the deficit or excess of clay or limestone is corrected. The slurry is then fed to rotary kilns where it is heated to the temperature necessary for calcination to incipient fusion. The resulting product, which is known as cement clinker, is exposed to the air for a few weeks in yards or compounds where it is left to "age." When quite mature, it is finely ground and stoied, and eventually packed in bags or barrels.

The Dry Process

When the clay is hard and shaly and when the limestone also is hard the dry process is used Both limestone and clay (in the correct proportions) are reduced to an impalpable powder which is then slightly moistened, thoroughly mixed in a pug mill and moulded into bricks. These bricks are dried and then burnt in kilns The clinker is very finely ground, turned out in yards for a few weeks and then stored or packed in bags and barrels. In this method no water is used during the grinding process

It may be remarked that in the works of the Katni Cement and Industrial Co., Ltd., the wet process is employed in the manufacture of cement. They use the Lower Vindhyan limestone which outcrops not far from their works. The deposits of clay also are not more than ¼ mile distant from the works. The clay is not sent to the works in the dry state but is reduced to a thin slurry and pumped to the factory. The advantage claimed for the wet process, is, that it ensures thorough mixing of the raw materials and, therefore, a constant composition of the resulting cement. Either the wet or dry process could be used at Sutna depending on whether the hard shales of the Upper Vindhyan were employed or the soft clayey deposits in the alluvium.

Table showing the Despatches of Limestone, Unslaked Lime, Slaked Lime, and Refuse Lime from Sutna Siding by the Sutna Stone and Lime Co., Ltd.

Year.	Limestone.		Unslaked Lime.	Slaked Lime	Refuse Lime.	Royalty paid to Rewa State.			REMARKS.
	Tons		Tons.	Tons	Tons	Rs	A.	P	
1901–02	646,228	Cubic Feet	FIGURES NOT AVAILABLE			....	..	..	
1902–03	1,448,374					...	.	..	
1903–04	646,228					...	..	..	
1904–05	nil					....	..	..	
1905–06	1,791,509					..		..	
1906–07						....	.	..	
1907–08	....					....	.	..	
1909	25,655		6,091	2,087	52	....		..	
1910		No	Records.	No Records	for 1910	....	..	..	
1911	17,535		9 121	644	82	..	.	..	
1912	37,341		18,891	1,104	63	....	..	.	
1913	34,782		15,088	920	81	...	.	..	
1914	28,958		15,830	1,358	17	6,785	7	0	2,026 Average number of persons employed from 1911 to 1919.
1915	31,838		17 124	1,787	62	7,470	12	0	
1916	36,020		14,727	1,315	159	7,498	2	0	
1917	65,721		15,429	1,443	184	11,352	12	0	
1918	70,424		15,955	9,361	865	13,071	14	0	
1919	62,807		16,729	1,892	87	11 282	7	0	
1920	53,978		24,809	4 562	763	12 069	15	0	1,935 Men 870 Women 203 Children, in 1920

XXIV. Iron Ores.

Historical

Iron ore occurs in many parts of Rewa State, notably, in the Beohari, Gopat Banas, and Deosar Tehsils. There is no doubt that iron was formerly manufactured on a large scale in various parts of the Rewa State from the Bijawar hematites and other iron ores Though the former activity of this old and well-known industry has greatly declined, still it is not unusual to come across the primitive indigenous smelting furnaces of the Indian smelter locally known as 'Agaria.' Even in the remote parts of Deosar and Beohari Tehsils and also in some parts of the Amarkantak plateau the writer has seen the primitive furnaces at work

Description of the primitive smelting furnace.

The furnaces used by the 'Agarias' of Rewa State are very small in dimension being only from 3 to 4 feet in height and capable of yielding from 10 to 15 lbs. of iron per day. They are usually built of clay and are slightly conical in form. There is an opening, near the bottom, either in front or at the side through which the bloom is removed at the end of the operation. It is plugged with clay while the blast is on. The apparatus for supplying a continuous current of air consists of a pair of strong circular wooden boxes about a foot in diameter and three inches deep These are covered with leather at the open end and very much resemble tambourines in shape. The leather cover is held taut by a thick strong string which passes through a small orifice in its centre, the other end of the string being tied to one end of a springy bamboo pole which is firmly fixed in the ground at the other end. A circular piece of leather attached to the string rests in

close contact on the inner side of the leather cover and operates as a valve When pressure is applied to the leather cover, this piece of leather prevents the escape of air through the orifice, and on the pressure being released it allows fresh air to be drawn in through the central perforation These tambourine shaped country bellows are operated by a man who stands on the two boxes and alternately presses and releases the leather covers by putting more weight on one side with one of his feet and by lifting the other foot. The blast thus produced by this peculiar movement of the operator's legs is led into the furnace tuyeres by bamboo pipes fixed near the base of the circular wooden boxes. (See Plates 1 and 2).

When starting operations a large charcoal fire is laid in the furnace and air forced by means of the bellows above described. When a high temperature is reached the furnace is fed alternately with ore and charcoal until it is about three-quarters full. From time to time the slag is removed through an orifice which is closed up soon after. At the end of the operation, which lasts from 4 or 5 to several hours according to the size and capacity of the furnace, the blast is stopped, the front orifice is opened, and the metal which is in the form of a pasty mass is taken out. As the slag is never completely removed by this method of smelting, it is essential to reheat and hammer the bloom and force the slag out. The smelters as a rule cut the bloom in two halves to show the quality of the metal to buyers. The ore used by the smelters is of the softer variety. About two parts of charcoal are used to one of ore. No flux is used for smelting the ore. Hundreds of small primitive furnaces are working in the whole of India even at the present day but none of the smelters use any flux. It is stated that the Waziris

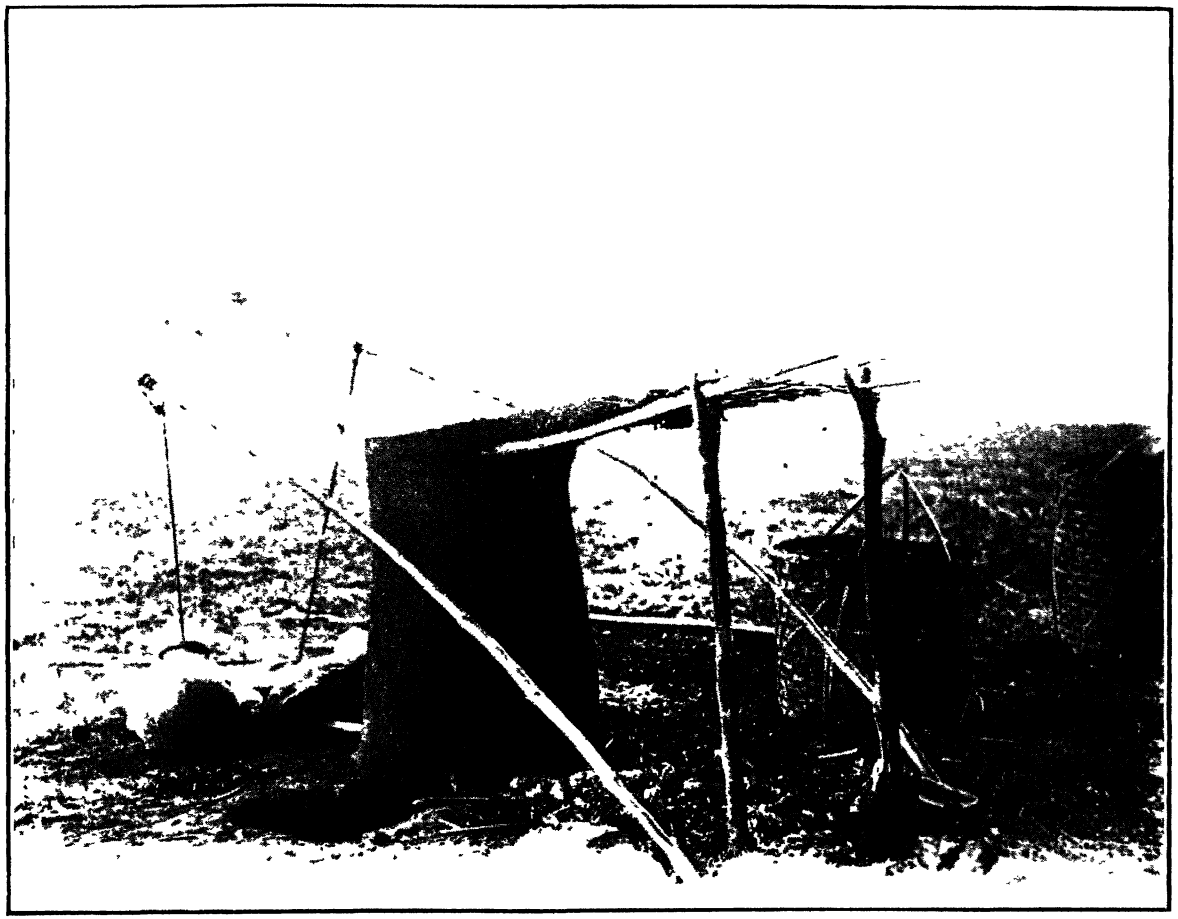

FIG 31
Primitive iron-smelting furnace as used by tho Agaiias of Rewa State

used nummulitic limestone for fluxing purposes in their furnaces.

Although this primitive method is very wasteful it must be conceded that the quality of the metal produced is quite good and it has always been held in high esteem by Indian blacksmiths on account of its purity and malleability. The metal is mostly used in the manufacture of agricultural and household implements such as hoes, ploughshares, sickles, pans, axes, spades, and the like.

CLASSIFICATION OF THE IRON ORES OF REWA STATE.

The iron ores of Rewa State occur in various formations and owe their origin to various processes :—

(1) Banded, ferruginous, cherty, and jaspideous quartz rock belonging to the transition rocks of the Bijawar series.

(2) Lenticular beds of small and large size having a high iron content, occurring in association with the above.

(3) Magnetite beds associated with ultra-basic rocks. This ore owes its origin to magmatic segregation.

(4) Magnetite beds occurring in the gneisses.

(5) Iron ore produced by the alteration and segregation of ferruginous schists and other ferruginous rocks of Bijawar age.

(6) Beds and nodules of quartzite iron ore occurring in the supra-Barakars.

(7) Lateritic iron ore formed by the segregation of iron oxide due to the weathering of rocks of later geological periods than the Bijawars.

The most important of these, are, ores belonging to classes 1, 2, and 3.

(1) and (2). The transition rocks of the Bijawar series extend in an east to west direction for nearly 120 miles from Bharouli (23° 54′ : 80° 54′) and Chilhari (23° 55′ · 81° 1′) in the west to Siphehi (24° 21′ : 82°) and Supreri (24° 18′ · 82° 49′) in the east, i.e. they cover about two degrees of longitude. In a north to south direction they occupy about 20 miles in the eastern part of the Deosar Tehsil. In these transition rocks of Bijawar age banded hematite quartz rocks and small and medium sized lenticular bodies of rich iron ore occur in many places within a length of about 90 miles from Bharouli (23° 54′ : 80° 54′) to Jiawan (24° 20′ : 82° 20′). The best ore occurs in the massive state and is compact or very finely granular. At times it is somewhat micaceous. It has a steel grey colour on a freshly fractured surface. Lenticles of rich iron ore are produced, most probably, by the leaching out of silica and segregation of iron oxide from the banded hematite quartz rock. It will be seen from the analyses given below that the phosphorus content is very low while titanium oxide is absent. There is no sulphur in many of the specimens while in some, there is only a trace of it. The iron content is very high in some cases and fairly high in others The following are analyses of various samples :—

	I.	II	III	IV
	Between Saru and Gondha (24° 22′ 82° 4′).	Between Namboah and Gujara (24° 20′ · 81° 56′)	Byriah (24° 20′ 81° 54′)	Near Karimati (24° 17′ · 81° 52′).
Iron	67·8	62·48	64 86	66·26
Manganese ..	trace	trace	042	·086
Sulphur	nil	nil	nil	trace
Phosphorus ..	·033	·038	·052	·064
Titanium Oxide ..	nil	nil	nil	nil
Insoluble matter .	4 00	5 62	4·42	3·02

FIG. 32
Agarias' primitive furnace, in operation

Photo. K. P. Sinor.

No. I was analysed by Mr. G. C. Mills, Chief Chemist, Tata Iron and Steel Co., Ltd. Nos. II, III and IV were analysed in the Geological Laboratory, Umaria.

A list of the more important places where iron ore of class 1 and 2 occurs is given at the end of this chapter.

(3). Magnetite beds associated with ultra-basic and basic rocks. Only in two places beds of magnetite associated with basic rocks have, so far, been discovered in Rewa State. One occurs near Umaria at a place known as Lodhairi (23° 29′ : 80° 49′); another, at a place known as Mainadhye (23° 56′ : 82° 38′) near Siddi in Singrauli. The first bed is in intimate association with hornblende and tremolite rocks, and sections of ore near the margin of the intrusion clearly show the presence of tremolite under the microscope. The depth of this ore-body has not yet been ascertained. It covers about a quarter square mile in area. The magnetite bed near Mainadhye is associated with a basic biotite sillimanite garnet rock of a very dark colour. It is somewhat smaller than the ore-body at Lodhairi. The following are analyses of the two ores:—

	Lodhairi [1] near Umaria.	Mainadhye in Singrauli.[2]
Iron	59·49	56·00
Alumina	4·62	..
Lime . ..	traces	..
Manganese .. .	,,	0·20
Sulphur .	,,	nil
Phosphorus . ..	..	0 091
Insoluble matter .. .	6·90	18·67
Titanium Oxide .. .	..	0·70

[1] The Lodhairi magnetite was analysed by Messrs D. Waldie & Co.

[2] The Mainadhye ore was analysed by Mr G C Mills, Chief Chemist, Messrs. Tata Iron and Steel Co, Ltd

(4). Magnetite beds occurring in the gneissic rocks.

Besides the Mainadhye magnetite there are three more beds of magnetite—two near Kadopani (23° 57' : 82° 43') and one near Usani (23° 56' : 82° 33'). The ore is largely intermixed with quartz. Other minerals which usually occur in the adjacent gneiss are also present in minute quantities. From an economic point these ores are not of any importance. A small patch of impure magnetite occurs in the metamorphic exposure near Panwar (23° 21' : 81° 54') about 3 miles to the south-west of Sidhi, in Gopat Banas.

(5). Iron ore produced by the alteration and subsequent segregation of ferruginous schists and other ferruginous rocks of Bijawar age.

Quite a lot of iron ore occurs among the transition rocks which owes its origin most probably to the weathering and alteration of ferruginous schists and the subsequent concentration and segregation of iron oxide. In some cases it is difficult to distinguish between iron ore produced by lateritisation as this process may be called and that produced by the concentration of quartz hematite rock by the leaching out of silica. In the majority of cases, however, ores formed by the first process contain a certain amount of combined water and are higher in phosphorus than ores belonging to class 2, above mentioned Important localities where ore of this kind occurs are mentioned in the list at the end of this chapter. The following analysis by Messrs. R. V. Briggs & Co. gives an idea of the quality of this ore :—

Iron Ore. Class 5. Naudiha (24° 12' 81° 32').

Iron	64 22%
Alumina	0·20%
Manganese	1 06%
Oxide of Titanium .. .	nil

Silica ..	..	..	. 4·00%
Phosphorus	..	.	.. 0·10%
Sulphur	..	.	Slight trace

(6). Beds and nodules of quartzite iron ore occurring in the supra-Barakar formations.

In some parts of the supra-Barakar formations iron occurs in the form of quartzite iron ore. The iron content is low and the silica content is very high in ores of this description occurring in Rewa territory. Economically, therefore, they are not very important. These ores were formerly used by the Indian smelters in their primitive furnaces and even at the present day they are used in those parts where soft and rich iron ores suitable for small furnaces are not available. The following are a few of the localities where such ore is exposed in Rewa territory not very far from a railway.—

At Chandia in association with clay beds (23° 39′ · 80° 45′).

At Barwar (23° 37′ · 80° 46′).

Near Bareri (23° 34′ : 80° 54′).

Near Bahargatta on the right bank of the Mahanadi River (23° 35′ · 80° 38′).

(7). Lateritic iron ore derived from rocks of a later geological period than the Bijawars.

Under this head are included all the laterites except those formed from Bijawar rocks. In Rewa State there are laterite deposits which are found in close association with traps and also with rocks of the Upper and Lower Vindhyan age. In a few cases, here and there, the lateritisation is so complete that the resulting product has become a rich iron ore but, on the whole, lateritic material contains a large amount either of alumina or silica, or of both, besides lime and magnesia.

The laterites of North Rewa occur in association with the Vindhyan rocks. The following are a few of the localities where lateritic material occurs:—

Sirgo, Andhi, and Zhalwar Hills north of Amarpatan.

Kotar and Bela Hills; Baijonath and Sirkini Hills, in Raghurajnagar and Huzur Tehsils.

Near Sulkma W. of Ramnagar, in Beohari Tehsil.

Laterites associated with trap rocks occur in South Rewa in the Amarkantak plateau and adjoining parts in the Maikala Hills.

Table showing the localities where iron ore occurs in Rewa territory.

Locality.	Class	Lat.	Longitude	Remarks.
Saru	1 & 2	24° 22′	82° 6′	Hematite.
Pokra	,,	24° 22′	82° 8′	,,
Kuchta	2	24° 22′	82° 2′	,,
Between Namboa . and	1 & 2	24° 18′	81° 56′	Hematite and Limonite.
Gujara .		24° 21′	81° 54′	
Gurjara ..	1	24° 22′	81° 56′	,,
Byriah .	1 & 2	24° 20′	81° 54′	,,
Katowli ..	1 & 2	24° 18′	81° 53′	,,
Karimati ..	2	24° 17′	81° 52′	,,
Gondha ..	2	24° 22′ 30″	82° 4′	,,
Near Khamaria ..	1	24° 22′	82° 16′	,,
Chilhari .	5	23° 55′	81° 1′	Hematite and Limonite.
Between Bharouli .. and	5	23° 55′	80° 54′	,,
Bamangama ..		23° 57′	81° 3′	
Tikwa	5	24° 1′	81° 15′	Hematite.
Between Tikwa .. and	5	24° 1′	81° 14′	,,
Pausrer ..		24° 3′	81° 16′	,,
Near Bhanni ..	5	24° 7′	81° 25′	,,

Locality.	Class.	Latitude.	Longitude.	Remarks
Nauriha, Girar Tola ..	5	24° 12′	81° 32′	Hematite and Limonite.
Near Chahli .	2	24° 16′	82° 11′	"
Churkimata ..	5	24° 17′	81° 45′	Hematite.
Lodhairi (near Umaria). .	3	23° 29′	80° 49′	Magnetite.
Mainadhye ..	3	23° 58′	82° 38′	"
Kadopani .	4	23° 57′	82° 43′	"
Usani	4	23° 56′	82° 33′	"
Bahargatta .	6	23° 35′	80° 38′	Hematite and Limonite.
Barwar .	6	23° 37′	80° 46′	"

XXV. Ochres.

Ochres consist largely of hydrated oxides of iron mixed with varying quantities of clayey or earthy material. The colours frequently met with are yellow, red, and brown, though ochres having pink, chocolate, and lavender grey colours are not altogether unknown The principal deposits of ochre occur in Rewa State in two places—one, at Semaria (29° 52′ : 81° 13′) in Raghurajnagar Tehsil in Northern Rewa territory; the other, at Bharouli (23° 55′ : 80° 55′) in Bandogarh Tehsil in Southern Rewa. Both these deposits are of economic importance but both suffer from a similar drawback, namely, distance from a railway.

YELLOW OCHRE DEPOSIT AT SEMARIA.

Semaria is situated in Raghurajnagar Tehsil It is at a distance of about 18 miles as the crow flies from Jaitwara Railway Station on the E.I. Railway. Yellow ochre occurs in a hill to the south-west of Semaria. The geological formations belong to the Lower Bhander (Bundair) division of the Upper Vindhyan series. In the yellow ochre hill they consist of limestone, shales and sandstones. The limestones occur near the bottom of the hill, the sandstones form the top, while the shales occupy the middle division. The ochre-bed occurs underneath the topmost sandstone bed. The section near the mine is as follows.—

	Ft.	In.
Overburden consisting of sandstones, frequently ripple-marked, embedded in alluvium ..	10	0
Rock consisting of altered sandstone converted in parts to yellow and red ochres ..	10	0
Bed of yellow ochre with only a few thin veins of red ochre ..	9	0

FIG. 33
Yellow-ochre mine, Semaria, Rewa State.

Photo K. P. Sinor.

The part below the yellow ochre bed is hidden by large detached blocks of yellow ochre and by debris. Both the red and yellow ochres are important from an economic standpoint. The yellow ochre is locally known as "Ramraj"; the red ochre is known as "Geru." The yellow ochre in the lower bed is of a somewhat lighter hue than the one which occurs in the bed above it. Unfortunately, the bright-coloured yellow ochre is intimately associated in some parts with red ochre and is also more siliceous than the former. In the lower bed of the ochre there is a clear thickness of 7 to 8 feet of good soft yellow ochre. The dip of this bed is very slight in a northerly direction. There is quite a lot of ochre in the hill mentioned above.

Inferior ochre in the Kotar Kemari Hill near Abair

Near the village Abair which is situated at a distance of about 10 miles to the S.W. of Semaria there is a hill known as Kotar Kemari in which yellow ochre of poor quality occurs. The section from the top of the hill to the bottom is as follows :—

Large blocks of laterite resting on earthy matter and altered sandstone.

Sandstones (ripple marked).

Limestones.

In some parts of the sandstone-bed yellow ochre occurs but it contains a lot of silica and is not, therefore, of any commercial importance. Not far from the place where the yellow ochre is exposed there was found a thin vein of soft pinkish yellow shales much resembling a coloured crayon. The colour of these soft shales is very pleasing but unfortunately they occur in very small quantity. The limestones which occur extensively near the bottom are very cherty.

YELLOW OCHRE DEPOSIT AT BHAROULI.

Yellow ochre occurs at Bharouli in the Bandogarh Tehsil in Southern Rewa. Bharouli is situated at a distance of about 25 miles from Chandia Railway Station on the Katni Bilaspur branch line of the B.N. Railway. The yellow ochre occurs in the shape of beds in the supra-Barakar formations at different horizons. The lower bed which occurs at a depth of about 5 feet from the surface level is overlain by about 3 feet of soft white sandstone and about 2 feet of alluvium. The thickness of this ochre bed is 10 feet. Another bed occurs in the hill to the N.W. of the village. The thickness of this bed is 6 feet. The section from the top of the hill to the ochre bed is as follows:—

(*a*) Ferruginous sandstone.
(*b*) White sandstone.
(*c*) Yellowish sandstone.
(*d*) Yellow ochre.

The yellow ochre bed rests on sandstones. The topmost bed contains some red and yellow ochre concretions.

The ochre bed which occurs near the general surface of the ground has a somewhat brighter colour than the bed which occurs midway on the hill close to the village. Both the beds are, however, of economic importance, as the ochres are soft and free from gritty matter. It is quite likely that other ochreous beds occur in depth. The ochre beds occur in much the same way as the beds of fireclay which occur between Chandia and Umaria, the only difference being that in the one case the clay is uncoloured while in the case of the Bharouli beds the clay has been impregnated with hydrated oxide of iron in a very fine state of division by percolating waters. The Bharouli ochre beds have not been worked to any large extent because of their distance from a railway.

POSSIBILITIES OF DEVELOPMENT OF THE OCHRE DEPOSITS AT SEMARIA AND BHAROULI.

As stated before, the chief drawback to the successful utilization of the ochre deposits of the Rewa State is their great distance from a railway. If the deposits were 6 or 7 miles distant from a railway station the writer would strongly have advocated the construction of a small tram line or an aerial ropeway. As the distances between Jaitwara Railway Station and Semaria, and between Chandia Railway Station and Bharouli are much greater the construction of a ropeway or a tram line is out of the question The ochre could be sent on pack cattle from Semaria to Jaitwara and from Bharouli to Chandia but only small quantities could be handled in this way owing to the great distance; freight charges also would be very heavy. Besides its distance from a railway the Semaria ochre suffers from another disadvantage, namely, the occurrence in Panna, Sohawal, and Kothi States of brighter ochres within a radius of about 10 miles from Jaitwara Station. If Semaria ochre was worked on a large scale it would have to compete with these ochres which would not be feasible owing to its longer distance from Jaitwara.

Bulk samples of Bharouli yellow ochre had been sent to London some years ago to the well-known firm of Messrs. Reeves and Sons, manufacturers of paints and colours It was, however, found that there was not much demand for it. Messrs. Reeves and Sons were of opinion that in order to introduce Rewa ochre to the English buyers it was essential to place the material on the English market at a low figure to start with. Rewa ochre in common with other minerals of the Rewa State suffers, however, from the drawback of being miles away from the sea-

board and hence exporting it to England or other countries is impracticable. It is true that large quantities of ochre are imported annually into England. France used to send more than 10,000 tons of yellow ochre annually to England before the war. In the English market, French ochre is considered to be of first quality; ochre from Italy, a bad second; German ochre, a good third; Peruvian ochre occupies the fourth rank while Spanish and English ochres occupy the fifth and sixth rank respectively. If conditions were favourable it would have been worth while to export Rewa ochres to England. As matters stand at present, the best thing would be to find a market for these ochres in India

The value of all ochres depend on their beauty and strength of colour. French ochre is said to be fairly strong while Peruvian ochre is considered to be stronger even than French. Bharouli ochre was stated by Messrs. Reeves and Sons to be less strong than French. However, if the ochre was treated with water and levigated its colour would be stronger than its colour in the natural state. There is always a certain amount of gritty matter in ochres. If levigated with water and treated properly the heavier siliceous material would sink to the bottom. There would thus be a separation of the colourless gritty matter from the fine particles of coloured clay. Due to the concentration of the coloured particles the resulting colour effect would be brighter. If the Semaria and Bharouli ochres were properly levigated with water and concentrated, the resulting products would be brighter and probably equal in quality to the ochres at present mined and treated near Jaitwara. In the treatment proper, the native ochre is ground under an edge-runner with water and the product is run into settling pits. Coarse sand settles first and fur-

ther away, the sediment consists of fine ochre which is dug out and dried.

Besides the natural ochre, Rewa State possesses large quantities of iron oxide in the form of laterites. It would be quite feasible to manufacture oxide of iron powder from the softer laterites of the Maikala range, specially, those of the Amarkantak plateau. Unfortunately, this part is more than 10 miles distant from Pendra Road Railway station on the B.N. Ry. Besides these deposits there are other deposits at Sirkini (24° 34′. 81° 27′), Kotar (24° 42′ 81° 1′), Bela Hill (24° 37′: 81° 8′), Baijonath (24° 30′. 81° 13′), and Andhi Hill (24° 29′: 81° 5′). The laterite which occurs on the Amarkantak plateau in South Rewa is closely associated with basic volcanic rocks (trap) while those of North Rewa mentioned above occur as a capping to the Bhander sandstones, limestones, and shales. All these deposits are far from a railway. The deposits of laterite nearest to a railway are those which occur in the low hills near Sutna, to the east of the railway line. These could be made use of, on a small scale.

Oxide of iron powder.

For the manufacture of oxide of iron powder the most essential thing is to reduce the laterite or soft ochreous hematite to a very fine state. For this purpose jaw-crushers, ball mills, and tube-mills would be required. The final product must be impalpable. Oxide of iron powder is largely used as a paint for general ironwork, such as girders, bridges, roof-trusses, etc. It is non-corrosive and resists weathering well One cwt. of the powder requires from 10 to 12 gallons of thinnings in the proportion of seven parts of boiled linseed oil to one of turpentine. Rewa State produces a large quantity of linseed annually. The oil expressed from these seeds could very well be utilized in the manufacture of paints

XXVI. Copper.

Copper ore has not been found in workable lodes anywhere in Rewa State but the writer has seen indications of copper, mostly in the form of encrustations of copper carbonate, in six places, two of which are in the Beohari Tehsil and four in the Gopat Banas Tehsil. One of the places, namely, Cherka (in Beohari) has been mentioned by Oldham in Vol XXXI, part 1, of the *Memoirs of Geological Survey of India* but the other five localities had not been noted before The following is a list of the places where traces of copper ore occur:—

Cherka (24° 5′ · 81° 20′).
Dhandu Kua (24° 3′. 81° 19′).
Gujara (24° 20′ : 81° 54′).
Byriah (24° 21′ : 81° 54′).
Gurjara (24° 22′ · 81° 56′)
Kuri, S E of Maharajpur (24° 24′ : 82° 0′)

The geological formations at all the five places consist of Bijawar (sub-metamorphic) rocks such as slates, shales, horny quartzites, veins of quartz, and quartz schists.

Cherka copper mine.

At Cherka which is 7 miles to the north-west of Beohari there is an old copper mine at a distance of 1½ miles to the north-east of the village. This mine is known as "Surkh Khadán." The only vestiges that now remain of this old mine are a very narrow incline descending at an angle of about 20° and a large hollow which has evidently been caused by the falling in of the old mine. Though the incline is still open at the surface it is almost impossible to enter it as it is used by innumerable bats as a refuge during the day. An attempt was made to drive them away

by lighting a fire a little way down the incline but this made them recede farther inwards. The walls of the incline were found to be coated with the green carbonate The size of the hollow formed by the subsidence of the old workings is about 200 feet long, 50 feet wide, and about 15 feet deep. What was the size of the old mine, how far the galleries extended, and what was the depth of the workings are questions about which nothing is known. Even the old residents of Cherka could give no information about this mine. It is, therefore, evident that the mines were worked in bygone times and not within the memory of living men.

Dhandu Kua old copper mine.

There is another old copper mine 2½ miles to the south-west of Cherka at a place known as Dhandu-Kua. The geological formations at this place consist of purplish and dark-grey slates as at Cherka. Quartz schist also occurs in this place. All that now remains of the old mine is a hollow somewhat larger in dimensions than that at Cherka The copper is found as an encrustation on the slates and schists not only on the exterior but also along the planes of parting and schistosity which clearly shows that a liquid charged with some copper salt had permeated the schists and slates. This old mine at Dhandu Kua is known as "Soon Kharcha." It does not look as if the hollow here was caused by the subsidence of old workings. It very likely represents an old opencast working.

Old copper mine at Byriah.

There is another old copper mine at a place known as Byriah, five miles to the south of Sidhi (24° 24′ 81° 57′). This mine is situated close to the village. Besides the slaty rocks met with at Cherka and Dhandu Kua there is an exposure of carbonaceous shales impregnated with copper.

Heavy stains of copper were also observed on the hematites which occur plentifully near the shaly outcrop. The old mine is situated in one of the hills to the south of the village. The entrance to this mine is about 2½ feet in diameter, just large enough to enable a man to pass through Attempts had been made to enter this to find out the extent of the old workings but about 15 to 20 feet from the mouth, the passage was barred by heavy blocks of rock. In the western part of this hill also the rocks are highly stained with malachite and it appears that here also some work had been done in former years and the richer pockets were worked out.

Gujara cupriferous outcrop.

About a mile to the north-east of Byriah there is another outcrop of cupriferous shales not far from the village of Gujara and close to the road leading from Barambaba to Sidhi. The shale which is carbonaceous consists in some parts of thin strings and partings of a soft micaceous schist and it is along these veins that the copper solutions must have effected their entry. Where the shale is thus run over by thin veins and partings of the soft schistose rock the staining is bright. The shale resembles dull coal of a poor quality, and by two previous observers it had been mistaken for graphite Prospecting work seems to have been done in early times at this place The rocks which occur not far from the shaly outcrop consist mostly of horny quartzites. It was intended to put down a bore-hole close to the shaly outcrop but owing to the long distance of Gujara from Sutna Railway Station and for other reasons the project had to be abandoned.

Gurjara.

Another locality where traces of copper occur is situated to the south of Gurjara which is about a mile and a half to the north-

east of Gurjara. Copper-stained carbonaceous shales could be traced for nearly one mile in one of the streams close by. Some prospecting or mining work seems to have been done in this part also. The carbonaceous shales were also traced at another place three miles to the north-east of Gurjara in the hills to the south of Maharajpur (24° 23′ : 81° 57′).

In all the cases mentioned above, the copper salts have been deposited along fissures and in cracks and crevices in the case of the hard rocks and along the planes of bedding and schistosity in the case of shales and schists. The shales being porous are more impregnated than the schists and hornstones and even in those cases where there was no visible encrustation the shales were found to contain copper when tested The proportion of copper is very small, ranging from ½ to 3 per cent The higher proportion was found only in the case of a few select specimens containing strings of malachite. Whether the original copper ore occurs in the form of sulphide or oxide is not known nor is it known whether any lode or large ore-body exists in depth. What is the original source of the copper salts which form an encrustation on the slates and schists is also not known at present. The copper-stained rocks at Byriah, Gujara, Gurjara, and Kuri evidently belong to the same horizon and occur in the same belt of sub-metamorphic rocks It is probable that the original home of the copper ore is the diorite which occurs in the shape of dykes and bosses in some parts among the transition rocks One such intrusion could be seen not far from Gujara.

On Sherwills' map of Bengal, Tagwa (24° 16′ : 82° 1′) was marked as the site of a copper mine. The writer, however, could not find any traces of a copper ore or of an

old mine anywhere near Tagwa. According to R. J. W. Oates there is an old copper mine at a place known as Khursa (24° 20′ : 82° 16′), four miles to the west of Jiawan. There are four excavations at that place—one large and three small—but in none of these did the writer of these notes see any trace of copper. The excavated rock consisted of purplish slates but even close observation failed to reveal any copper staining on them.

Alleged occurrence of copper at Tagwa and Khursa

XXVII. Lead.

Sulphide of lead otherwise known as galena had been discovered some years ago at Urghari (24° 14′ : 82° 29′) in the Deosar Tehsil.

Urghari galena mine.

The first to prospect this deposit was R. A. D. Sewell who, according to Oldham, had found in 1892–93 a vein of galena and quartz about 9 inches thick at a depth of about 30 feet from the surface Samples of galena obtained during prospecting operations had been sent to the Geological Survey of India and are said to have yielded on assay 61·6 per cent of lead, and 7 oz. 16 dwt. and 14 gr of silver to a ton of lead When the writer first visited this locality the old mine was full of water. When the water was baled out it was found that the hollow was partly covered with debris and no indications of a vein of galena could be seen. In the old heap lying on the surface a few specimens of decomposed gneiss containing some galena were found. A new pit was sunk to the north-east of the old hollow but it proved to be absolutely barren up to a depth of 25 feet from the surface. The old excavation is oval in outline, and is about 110 feet long and about 25 feet wide. A small pit was sunk in the north-western end of this old excavation which proved to be somewhat more promising than the other as the rock excavated contained some galena. However, the indications were not tempting enough for a further outlay of expenditure. The depth of the small pit from the surface is about 30 feet. Definite results would have been obtained by putting down a bore-hole by means of a small diamond drill operated by hand. For those who in future years may be tempted to prospect this deposit we would recommend a diamond drill as the

only means of arriving at conclusive results quickly Even if a thick vein of galena were met with in depth, the economic importance of such a deposit would be problematic as Urghari is in a very out-of-the-way place and very far from a railway.

Alleged occurrence of lead and silver in the Sohagpur Tehsil

In "Manual of the Geology of India," Part III (Economic Geology), by Ball, it is stated that according to Capt. Pearson there was a silver mine in Sohagpur formerly worked by a Raja and it is suggested by the author that this mine was probably a lead mine containing galena which almost invariably contains a small proportion of silver No details are available as to the exact locality in Sohagpur Tehsil where this mine was situated. In this Tehsil there are exposures of granitic intrusions in the older rocks in which it is quite possible that galena may occur but, so far, no metalliferous vein or lode has been found in the gneissic or granitic rocks of this locality.

Occurrence of galena in Rhotas Limestone.

Galena occurs in small quantities in the Rhotas Limestone, a formation which runs for miles at the foot of the Kaimur range. As the galena occurs in the form of minute strings and small crystals the occurrence is not of any economic value.

XXVIII. Mica.

Mica in Bardghattá pegmatite.

Mica occurs at Bardghatta (23° 58′ : 82° 47′) in Singrauli, 2 miles to the south-east of Pipra. It occurs in a tourmaline-pegmatite rock in a low-lying ridge about 300 yards long and 50 yards wide running in an east to west direction. The pegmatite which is very coarse consists chiefly of quartz, muscovite mica, tourmaline, and felspar. The tourmaline is of the black variety known as schorl. Some of the tourmaline crystals have beautiful outlines and are from 1 to 2 inches across. Prospecting work which had been done at this place in 1912 revealed sheets of mica from 2 to 4 inches square. The depth of the trial pits was about 15 feet. It is very probable that if this vein were followed in depth larger sheets of mica would be met with.

Mainadhye pegmatite.

Another locality where a similar coarse pegmatite occurs, is near Mainadhye (23° 58′: 82° 38′), 6 miles due west of Pipra. The pegmatite occurs in a small hillock. The exposed parts did not reveal mica sheets of a workable size though it is likely that an extension of this rock in depth may be found to contain large sheets. These pegmatites of Singrauli are probably the continuation of similar rocks of Behar in which mica mines are worked.

The great distance of Bardghatta and Mainadhye has been a bar to vigorous prospecting work. A railway from Daltonganj through Pipra to Katni or to any station on the Katni Bilaspur branch line of the B N. Railway would be the means not only of opening out the corundum field and coal-fields which occur in Singrauli but may also be the means of locating and proving other deposits like the above mica deposit.

XXIX. Fire-clay.

General characters.

The value of fire-clays lies in their capacity for withstanding high temperatures. They contain more than 60 per cent of silica and about 20 per cent of alumina. Their general chemical formula is Al_2O_3, 6 SiO_2. The water content is variable. They also contain small proportions of lime, soda and potash. The smaller the quantity of alkalies, the more refractory is the clay Fire-clay is used largely in the manufacture of fire-bricks Suitable mixtures of fire-clay and other clays are used in the manufacture of glazed bricks, flooring tiles, drain-pipes, and other sanitary appliances. Besides refractoriness another essential quality in a fire-clay is its capacity to withstand sudden changes of temperature. Since both these qualities are not usually found in one and the same clay it is necessary to mix together two or more clays to obtain a first-class fire-clay. To prevent shrinkage on drying and firing fire-clay is mixed sometimes with clay specially burnt (grog)

Fire-clay deposits of Rewa State

Extensive beds of fire-clay occur in Rewa State in the Upper Gondwanas known as supra-Barakars. They extend from the Mahanadi River near Chandia (23° 39′ · 80° 45′) to Lodha (23° 35′ : 80° 50′) for more than 6 miles on both sides of the B N. Ry. line. Similar beds occur at Dubar and in the neighbourhood of Umaria The lateral extent of these beds is also considerable as fire-clay is found to occur as far west as Amdari. The beds are fairly thick, ranging from 3 to 7 feet in thickness. From an economic point these beds are very important. The deposits near Chandia are being largely worked by

the Katni Cement and Industrial Company who use the fire-clay in the manufacture of fire-bricks and glazed sanitary ware The quality of the Chandia fire-clay is quite good It is highly plastic and very refractory. The clay which occurs near Umaria is not so plastic as that which occurs near Chandia and Dubar. The following is an analysis of Chandia fire-clay:—

Loss on Ignition	6 64
SiO_2	70·54
Al_2O_3	21 62
Fe_2O_3	0 09
CaO	0·45
MgO	0 41
	99·75

(*b*) Fusing point = 1400°C

(*c*) Highly plastic.

(*d*) Absorption about 5 per cent

(*e*) Contraction = ¾″ per foot
= ¼″ on drying and ½″ on burning

The following shows the precise localities at which workable beds of fire-clay occur in Rewa State:—

(1) To the west of Chandia Ry. Station, between it and the Mahanadi River (23° 39′, 80° 43′)

(2) Near Dubar (23° 37′ : 80° 49′)

(3) Near Amdari (23° 28′ : 80° 38′)

(4) At Baroudi (23° 30′ : 80° 43′).

(5) Near Piparia and Koilari (23° 31′ : 80° 55′).

Prospects of a Fire-clay Industry at Chandia.

At present, only the deposit close to Chandia Railway Station is being worked. The deposits at Dubar and Baroudi are quite good, but unfortunately they are at distances of 5 and 10 miles, respectively, from Chandia Railway Station. There is, however, plenty of good material between Chandia and the Mahanadi River

as stated above. The proximity of Chandia to the Umaria Colliery is another point in favour of these deposits. There is every facility for establishing an industry at Chandia for the manufacture of fire-bricks, tiles, glazed and sanitary ware, etc., and there is no doubt that such an undertaking would be quite profitable.

Manufacture of fire-bricks

In the manufacture of fire-bricks the fire-clay is first ground and then pugged, and a plastic mass is produced by adjusting the clay mixture. From this plastic mass bricks are moulded either by hand or by machinery. The moulded bricks are then dried and burnt in kilns for about a week, the heat being gradually raised. During the final stages the temperature is maintained at a white heat.

Manufacture of glazed sanitary ware

For glazed sanitary ware the preliminary procedure is similar to that employed in the manufacture of fire-bricks. In this case, however, the object is to produce a material which would be impervious to water and the different clays are, therefore, mixed in such proportions as to produce an impervious ware. For sanitary pipes the prepared clay is fed into a pipe mill and forced through a die under great pressure. The rough pipe thus formed is then cut to the requisite length, after which it is finished, polished, and allowed to dry. The different pipes are then carefully stacked in a kiln and fired at first at a low heat and then to a temperature sufficient to vitrify the whole mass. The glaze is then added to the kiln. When quite cool, the finished sanitary pipes are taken out from the kilns. Besides the straight sanitary pipes other complicated fittings are also required for sanitary purposes These fittings consist of bends, taper-pipes, syphon traps,

gulley-traps, intercepting sewer traps, single and double junctions, etc These are all cast in plaster moulds, the same clay mixture being used as for pipes.

Production of fire-clay

The average production of fire-clay at the Chandia quarries for the five years 1916–1920 was 2,900 tons. The production in 1921 was 10,203 tons. Table showing the quantity of fire-clay annually produced at Chandia from 1915 to 1921 is given in the appendix.

XXX. Potstone.

An impure variety of steatite occurs near Sidhi, the headquarter of the Gopat Banas Tehsil (24° 24′ · 81° 55′). It is exposed in one of the tanks close to the village and also on both sides of the Herun River. This rock is really an altered talc-chlorite schist It is tough, has a greenish tinge, and is quite soft and soapy to the touch. It stands heat well. Potstone is usually fashioned into bowls, pots, pans, and other utensils. Being a refractory material, it is unaffected by fire. The purer and more compact form known as soapstone or steatite has not been found, so far, in Rewa State. There is little demand for potstone but there is a fair demand for good quality white, soft, and compact soapstone. It is used for paper-filling, cotton-sizing, and as a lubricant. The best quality is used in the manufacture of gas-burners and talc powder for toilet purposes.

XXXI. Felspar.

The felspars are minerals consisting essentially of silicates of alumina with varying proportions of silicates of potash, soda, magnesia, and lime and can be regarded as isomorphous mixtures of three primary minerals—namely, potash, soda, and lime felspars. The felspar which is generally used in the pottery industry is known as 'orthoclase' or potash felspar It contains about 16 per cent of potash, 18 per cent of aluminium, and 65 per cent of silica. Its fusion point is about 1300°C. (2372°F.). The common varieties have a higher fusing point. The pink colour of some felspars is due to a trace of oxide of iron which as a rule may be ignored, although the cream-coloured varieties are to be preferred.

Occurrence in Rewa State

Felspar occurs in some parts in South Rewa in the pegmatite veins associated with gneisses. Large crystals of felspar occur close to Narsara Nala (23° 32′ : 80° 51′). Other localities are Dhanwahi (23° 34′ : 80° 52′), Lodha (23° 35′ : 80° 48′), Kathai (23° 32′ : 80° 46′), and Dhangi (23° 31′ : 80° 47′). Good sized crystals of felspar occur also in the exposure of metamorphic rocks near Jaithari and Venkatnagar Railway Stations The variety which largely occurs at all these places is microcline, a triclinic potash felspar having the chemical composition and almost precisely the form of orthoclase.

XXXII. Soda and Earth Salt.

Soda

In some parts of Rewa State, notably in the Teonthar Tehsil in North Rewa, soda occurs as an efflorescence in the soil which is frequently found to be both saline and alkaline It occurs mostly in low-lying ground. The top layer of the alluvium is scraped off during the winter months No efforts are made to purify this material which is sold in its crude state. It is used for washing clothes The following are the localities at which this material occurs :—

Mouja	Tehsil
Baragaon (25° 0′ : 81° 50′).	Teonthar.
Sohagi (25° 1′ : 81° 46′)	„
Majgawan (24° 59′ · 81° 55′)	„
Kotar (24° 42′ · 81° 3′)	Raghurajnagar
Sohas (24° 42′ · 81° 0′).	„
Meoti (24° 43′ · 80° 59′)	„

Earth salt.

Impure salt occurs at a place known as Singarwar (24° 53′ : 81° 46′) in the Teonthar Tehsil in the saline alluvium. The saline earth is lixiviated with water and the brine (saturated salt solution) is allowed to evaporate in shallow pans from which sodium chloride separates out. The salt thus prepared is invariably mixed with earthy matter and chemical impurities such as magnesia and soda.

FIG 34.
Photograph showing an accumulation of trap-pebbles in the bed of the Johilla River near Birsingpur Railway Station.

Photo K P. Sinor.

XXXIII. Trap Pebbles.

Large, water-worn, rounded pebbles of trap occur in the bed of the Johilla River near Birsingpur Railway Station on the B.N Ry. These pebbles have been formed partly due to weathering and partly to the action of running water They occur in abundance near the union of the Ganjra Nala and the Johilla River. Similar pebbles are found in the Mahanadi River near Chandia (23° 39′: 80° 42′)

Use of trap pebbles.

Being hard and tough, trap pebbles are used in tube-mills for pulverizing limestone and clays or shales in the manufacture of cement and for grinding ochre, bauxites, and other minerals which are required in a very fine state of division for certain industrial purpose. Where pebbles of flint or quartzite are easily available they are used. In absence of these, trap pebbles are used. A charge of from 9 to 11 tons of pebbles is required when a tube mill of ordinary size is first started. Pebbles of sizes varying from 1½ inches to 5 inches in diameter are commonly used in tube mills. In 1919 the quantity of pebbles exported from Birsingpur to Katni was 210 tons. These pebbles were required by the Katni Cement and Industrial Co.

XXXIV. Garnets.

Garnets are silicates of aluminium, iron, manganese, chromium, calcium, and magnesium. They are all alike in their crystalline form and they have the same type of chemical formula. Different varieties of garnet have different colours The clear varieties are used as gemstones. Red, brown, and purplish-red garnet are of frequent occurrence Rose-pink and emerald-green garnets are somewhat rare Opaque varieties of garnet known as common garnet occur mostly in metamorphic rocks.

The clear gem varieties of garnet have not, so far, been found in Rewa State, but the common variety which is used as an abrading agent occurs in the metamorphic formations near Umaria. It occurs in garnet sillimanite rock, in garnetiferous hornblende rock, and in some cases in the gneiss itself The garnet which occurs in these rocks is, however, of no commercial value as the crystals are very minute and as it would be necessary to resort to crushing and concentration in order to separate them from other minerals with which they are intimately associated.

When crystals of garnet occur in soft micaceous schists it is neither very difficult nor very expensive to separate them. Such a garnetiferous schist consisting of mica, chlorite, and quartz, occurs near Bahargatta (23° 35′ : 80° 38′) in the bed of the Mahanadi River and on its banks. The garnet occurs as small dodecahedrons of a dark brown colour usually of the size of large pea-grains in this schistose rock which extends from one bank of the river to the other. That part of the rock which lies in the centre of the river, rises high above the usual water level and

gleams with a silvery lustre when the sun's rays fall on it. Owing to the small size of the crystals this occurrence also is not of any great economic value.

XXXV. Ballast and Road-metal.

In South Rewa, gneisses and associated rocks are largely used as ballast by the Bengal-Nagpur Railway Co., Ltd , for their Katni-Bilaspur branch line railway. The following table shows the quantity quarried within Rewa territory by the B.N. Railway and the royalty realized thereon from October 1917 to September 1921 :—

Year		Quantity quarried.	Royalty realized.	
		Cubic feet	Rs	A
Oct 1917 to Sept 1918	..	66,799	251	0
1918–19	..	88,584	332	3
1919–20	..	73,669	276	4
1920–21	..	122,025	457	10

Road-metal.

In North Rewa, both laterite and limestone are largely used for metalling roads. The total length of metalled roads which run through Rewa territory is 195 miles, of which the Great Deccan Road runs for about 87 miles from Amarpatan, *via* Rewa, to Hanumana Other important roads are the Sutna-Bela, Govindgurh-Bela, Rewa-Govindgurh, and Govindgurh-Ramnagar Roads. Figures showing the quantities annually quarried for road-metalling are not available. It would be worth while to keep a record of the production of all kinds of stone used for road-metalling in Rewa State

XXXVI. Semi-Precious Stones.

Agate, jasper, chalcedony, bloodstone, and associated siliceous rocks of semi-precious quality occur in the druses of trap rocks in many parts of South Rewa, notably in the Johilla Valley. The agate occurs in the form of small and large pebbles with beautiful concentric or parallel bands. The jasper is usually of the red, brown, or green variety. Sometimes, both red and green colours are found in the same specimen. Bloodstone also occurs as stray pebbles in the bed of the Johilla River near Birsingpur Railway Station (23° 22'· 81° 5') This river takes its source in the high trappean plateau of Mandla District near Amarkantak The distance between its source and Birsingpur is more than 60 miles. The agate, chalcedony, jasper, and other semi-precious stones occur in the druses of the amygdaloidal trap which covers a very large part of the plateau. By weathering, the stones get detached from the parent rock and find their way to lower levels through the agency of water. The detached fragments get water-worn during their transport and later get embedded in the surface soil. The best places for obtaining these semi-precious stones are those where the accumulation of earthy material is very great and which lie in the vicinity of rivers which drain the area covered by the trap rocks. Cornelians have not been found, so far, among the stray pebbles in the bed of the Johilla River but it is quite likely that they would be found in the alluvium. It is very strange that the pebbles of agate, chalcedony, and jasper occurring in the surface soil in the Johilla Valley have not yet attracted the attention of lapidaries. It may, probably, be due to the fact that

there is plenty of material in the valley of the Nerbada at Bheraghat or the Marble rocks, from which the lapidaries of Jubblepore derive the material used by them, that no notice has been taken of this locality

Amethyst and Quartz crystals:—In the trap rocks above mentioned amethyst is also frequently found. It has been noted *in situ* in some large druses in the trap rock near Kotipat Ghat which is about 7 miles to the south-west of Ghunghuti Railway Station. The colour of the amethysts found here is not very deep nor is it uniformly distributed but it is possible that if the area near Kotipat Ghat were properly worked some good material might be found.

Clear crystals of quartz occur in the Upper and Lower Vindhyan formations near Ramnagar in the Beohari Tehsil In the Chhuīya Ghat near Govindgurh small transparent crystals of quartz have been found to occur in association with white shales.

XXXVII. Building and Ornamental Stones.

The old crystalline formations and the rock formations of both the Upper and Lower Vindhyan Series afford very good building stone

Pathat sandstone.

The sandstone quarries at Pathat (25° 9′ : 81° 48′) are situated in Teonthar Tehsil in Northern Rewa. The village of Pathat is about a mile distant from Shankergudh Railway Station on the E I. Ry., close to Allahabad. The sandstone which occurs in this part belongs to the Kaimur group of the Upper Vindhyan formations The rock varies in colour from brownish, pale-buff, and greyish-white to almost pure white. The thin bedding, and joints, enable the quarrymen to obtain large slabs up to 10 feet long and varying from half an inch to three or four inches in thickness. These flaggy layers are eminently suitable for use as flooring slabs. Besides the thin-bedded flaggy variety there are massive beds free from joints and fissures from which large heavy blocks could easily be obtained. Table showing the production of Pathat sandstone during the years 1916–1920 and the royalty realized thereon by the Rewa Durbar is given in the appendix.

Other sandstones.

Sandstone of excellent quality for building purposes is obtainable in any desired quantity from the Kaimur, Rewa, and Lower Bhander groups of the Vindhyan System in many other parts of Rewa State but unfortunately all the noteworthy localities are far from a railway with the exception of the Pathat sandstone mentioned above.

As has been mentioned in a previous chapter there are extensive beds of limestone in Rewa State which

stretch from Sutna and Amarpatan to Rewa and Raipur Some of this limestone is used locally for building purposes. At Sohagi (25° 1′: 81° 46′) in Teonthar Tehsil, also, limestone of first-class quality occurs.

Limestone

Crystalline limestones.

Crystalline limestones occur in the eastern and southern parts of the Rewa territory. Their home is in the old crystalline rocks. Mention has already been made of these limestone bands in the chapter on limestones. The white and bluish white crystalline limestone of Majgawan (23° 33′ · 80° 49′) near Umaria deserves special mention because of its proximity to the railway line This stone is capable of acquiring a high polish and is beautiful in appearance which is, at times, marred by earthy veins and patches running through it.

Gneisses and granites.

In South Rewa, gneisses and associated rocks largely occur close to the B.N. Railway line. Hitherto, however, they have not been made use of, except as ballast. The writer, however, wishes to emphasize the fact that material suitable for use as ornamental stone occurs in many parts in the old crystalline rocks in Rewa State. About two miles to the north-east of Jaithari Railway Station (23° 2′: 81° 50′) a beautiful gneissic rock with large cream-coloured porphyritic crystals of felspar occurs. There is another rock in the same locality in which small flesh-red crystals of felspar occur in a dark matrix. When polished, this rock presents a very pleasing mottled appearance. Near Venkatnagar Railway Station beautiful gneisses quite suitable for use as ornamental stones occur in large quantity. The pink and reddish colours of the felspars and the dark colour of the biotite produce a contrasty effect quite

pleasing to behold. There are three inliers of metamorphic rocks in South Rewa close to the railway line—one near Umaria and Lodha (23° 35′ : 80° 48′), another near Birsingpur Railway Station (23° 22′ 81° 5′) and the third between Jaithari and Venkatnagar. In all the three inliers of the old crystalline and metamorphic rocks suitable material both for building and ornamental purposes could be obtained. Besides the ordinary gneisses, rocks containing hornblende, felspar, garnet, and serpentine also occur Some of the dark coloured hornblende felspar rocks are capable of acquiring a high polish.

Venkatnagar granite.

A rock which deserves particular mention is the finely crystalline pinkish-grey granite which occurs near Venkatnagar Railway Station. When well polished this rock has a very pleasing appearance. Polished pillars made of this material would have the combined virtues of beauty and durability.

Gneiss of Deosar and Singrauli.

In Deosar Tehsil and Singrauli Ilaka gneisses suitable for building and ornamental purposes occur in many localities but owing to their distance from a railway they are of no economic importance at present.

Possibility of utilization.

The builders and stone-dressers of Rewa State have hitherto paid their attention mostly to the sandstones which lend themselves easily to quarrying, dressing, and carving. There is not a single large edifice in Rewa State in which gneisses or granites are used. The great hardness of these rocks, their massive structure, and the absence of joint planes and fissures have proved a bar to their successful exploitation. With proper machinery, however, these difficulties could be overcome. If there

was a fair demand for material of this kind there is no reason why the Rewa State gneisses and granites could not be turned to profitable account.

PART IV.

POSSIBILITY OF MANUFACTURE OF ALUMINIUM IN REWA STATE.

PART IV.

POSSIBILITY OF MANUFACTURE OF ALUMINIUM IN REWA STATE FROM THE BAUXITES OF AMARKANTAK PLATEAU AND OF KATNI AND BIJERAGHOGARH.

Introductory

For the manufacture of aluminium the most essential requisite is cheap power. The next important item is an abundant supply of bauxite containing a high percentage of alumina and a low percentage of iron and silica. In the following notes both these factors are discussed in detail. The composition and general characters of bauxite and the known occurrences of important deposits of this mineral both in India and abroad are first dealt with. The chief processes used in the manufacture of alumina are next described. The question regarding generation of power in Rewa State at a sufficiently cheap rate to make the manufacture of aluminium a commercial success is then discussed by the writer.

XXXVIII. Composition and General Characters of Bauxite.

Bauxite is an impure hydrated oxide of aluminium. In appearance it is earthy and occurs chiefly in the massive state, though oolitic and pisolitic varieties are not uncommon. When not admixed with impurities it is of a greyish white colour. Usually, however, it contains varying quantities of oxides of iron and titanium, silica, lime, and magnesia. The presence of iron oxide gives the

mineral various hues of red, yellow, and brown. It contains a variable proportion of alumina and iron oxide. With increasing percentage of iron oxide it passes into laterite. Although there is no hard and fast rule to distinguish bauxites from laterites it may be stated, in general, that specimens containing less than 35 per cent of alumina and more than 30 per cent of oxides of iron and titanium may be said to belong to the class of laterites

This mineral takes its name from the district of Baux near Arles in France where it was first discovered by Berthier. Deposits of bauxite occur in many parts of the world but the most noteworthy deposits are those of France where the mineral occurs in the Departments of Ariege, Charente, Bouches du Rhone, Herault, and Var. The French bauxites, besides being extensive, have a very high alumina content. Bauxite also occurs in large quantities in Georgia, Alabama, and Arkansas in America; at Abruzzi in Italy; Larne in Ireland; Wochein in Austria; and British Guiana in South America. The chief Indian deposits are situated in the Baihir Plateau in Balaghat District; at Bijeraghogarh and Katni in the Jubblepore District; in Kalahandi State and Chota Nagpur; in Bhopal and Rewa States; and in Satara District.

Mode of occurrence

The bauxite deposits of France and those of Alabama and Georgia in the United States occur in regular beds or as irregular masses in association with limestone. Bauxite also occurs in beds and masses embedded in clay as at Oberhassen and Vogelsburg in Germany and in some parts of the Alabama District. It also occurs in association with basic eruptive rocks, chiefly basalts, as in Westerwald and Vogelsburg in Germany, Puy-de-Dome District of France, and notably in Ireland and in India. Regarding the

mode of origin of this mineral there is some diversity of opinion, some attributing its formation to hydro-thermal action while the majority believe it to have been formed as the result of subaerial action of acidulous waters on rocks containing aluminium silicates such as granites, syenites, and basalts. The hydro-thermal origin applies to some of the bauxite deposits of the south of France Those deposits of bauxite which are intimately associated with basaltic rocks are believed by some to owe their origin to an obscure metasomatic process. The deposits of Arkansas in North America, of the coastal country of the Mediterranean, Auvergne, and Wochein District of Austria appear to be independent of metasomatic action and owe their origin to the process of weathering and disintegration of the felspathic ingredients of igneous rocks.

BAUXITE DEPOSITS OF REWA STATE.

The bauxite deposits of Rewa State occur both in the northern and southern divisions of Rewa territory. Those of the southern division which occur in the Maikala Hill range are very extensive and richer in alumina than those of the northern division which occur in a very limited area in the Sirgo, Andhi, and Jhalwar Hills between latitudes 24° 20′ and 24° 30′. In the eastern part of the Maikala range there is a plateau extending for miles in a N.W. to S E. direction. This plateau derives its name from the village of Amarkantak on which stand the famous sacred shrines built by Karna Chedi in the 11th century The rivers Sone, Nerbudda, and Johilla all have their source near Amarkantak Of these, the Sone and Johilla continue their course for many miles within Rewa territory while the Nerbudda forms the boundary between the Rewa State and Mandla District for nearly 40 miles and

then flows through British territory. That part of the plateau which is situated within Rewa territory covers an area of about 800 square miles, the greater part of which lies in the Sohagpur Tehsil. It is, however, only in the southern part near Amarkantak and Umergohan, and in the range of hills north of the Nerbudda River between longitudes 81° 30′ and 81° 45′, that bauxite of good quality occurs.

Geological formations.

The geological formations of the eastern part of the Maikala range consist of gneisses, Lameta beds, trap, and laterite. The gneisses occupy the lower part of the hill ranges forming the plateau while the traps which cover the whole of the plateau have a thickness of more than 1,000 feet. The Lameta beds which mostly consist of calcareous sandstones with cherty and chalcedonic segregations and clay pellets are exposed between the gneisses and the traps The trap is, in turn, covered by laterites and, here and there, by rich beds of bauxite.

Localities where good bauxite occurs.

The following is a list of places where bauxite of very good quality occurs plentifully :—

1. Amarkantak (22° 40′ : 81° 47′).
2. Umergohan (22° 45′ : 81° 48′).
3. Chita (22° 46′ : 81° 46′).
4. Miria (22° 48′ : 81° 45′).
5. Harai (22° 48′ : 81° 42′).
6. Mohodih (22° 48′ : 81° 41′).

Bauxite of somewhat inferior quality occurs in many parts of the plateau, of which the following may be mentioned :—

(*a*) Between Amarkantak and Kabir Chautra.

(*b*) Between Kapildhara and Daunai.

(*c*) Between Daunai and Damgar.
(*d*) Between Amarkantak and Umergohan.
(*e*) At Khapripani and Barbaspur

Other elevated parts such as those near Badharghar, Ladhor, Bahmangarh, and Lakaorighar to the north and north-west of Umergohan also contain some bauxite but specimens obtained so far were found to be highly ferruginous

COMPOSITION OF BAUXITES OF THE AMARKANTAK PLATEAU

As stated before, bauxite has a variable composition. It is not a mineral with a definite composition but rather a rock composed of various colloidal aluminium hydrates mixed with oxides of iron and titanium, lime, magnesia, and clayey matter. While certain bauxites (such as the French bauxites) show a fairly consistent composition it may be stated that the bauxites of the Amarkantak plateau differ in this respect. The composition varies not only in specimens from different localities but also in specimens collected from any particular part. The varying composition is chiefly due to a larger or smaller percentage of oxides of iron and titanium. The bauxites of different parts of the plateau may be divided into four classes :—

1 Hard, massive, pisolitic, greyish-white, grey, yellowish, and cream-coloured bauxite containing from 55 to 65 per cent of alumina and from 5 to 10 per cent of oxides of iron and titanium.
2. Fairly hard, distinctly oolitic, reddish-grey, grey, and purplish bauxite containing from 50 to 60 per cent alumina and from 12 to 20 per cent of iron and titanium oxides

3. Fairly soft, highly ferruginous, reddish bauxite, containing from 40 to 50 per cent of alumina and 15 to 25 per cent of oxides of iron and titanium.
4. Very highly ferruginous, soft and hard varieties of oolitic and concretionary bauxite containing 35 to 40 per cent of alumina and 30 to 35 per cent of iron and titanium oxides.

The bauxites of Umergohan, Chita, Miria, and Mohodih belong to the first class, while those of Amarkantak belong mostly to the second class Bauxites of class three and four occur abundantly in many localities

Large samples of the above varieties, after very careful sampling, gave the following analyses :—

Locality.	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	H_2O
Umergohan (Class I) ..	57·07	2·73	8·75	0 25	0·28	1·14	29·30
Amarkantak (Class II) ..	51 39	8 61	10 10	trace	0 27	1·38	27·88
Kabir Chautra (Class III) .	48·98	17 22	5 80	trace	0·27	3·80	23·50
Amarkantak (Class IV) ..	38 88	27·27	7 00	trace	0·18	4·53	21·52

The above were analysed by Messrs. R. V. Briggs and Co., Calcutta.

Analyses of select specimens of Umergohan, Mohodih, and Miria bauxites gave the following results :--

Locality	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SiO_2	H_2O
Umergohan. (Lat 22° 45′. Long 81° 48′) ..	62·32	2 45	6 26	0 15	0 19	1 08	27 22
Mohodih. (Lat 22° 48′ Long. 81° 41′) ..	66 04	1 09	4 31	trace	0 32	0 36	26 85
Miria (Lat 22° 48′ Long. 81° 45′)..	64 68	2 26	5 32	0 11	0 25	0 62	26 52

The above were analysed in the Umaria Laboratory, Rewa State.

The best material occurs in pockets and in regular beds in many parts of the plateau. The quantity of available bauxite of fairly good quality similar to that represented by classes I and II is very large while stuff similar to that represented by classes III and IV is practically inexhaustible. The only drawbacks for the successful utilization of these deposits are (1) their peculiar geographical position to which they owe their inaccessibility and (2) their distance from a railway Both these difficulties could be overcome by constructing an aerial ropeway to carry the bauxite in specially constructed receptacles from the plateau to Pendra-Road railway station on the Katni Bilaspur branch line of the B.N. Railway. The distance between Amarkantak and Pendra-Road railway station, as the crow flies, is about 9 miles. At present there is only a cart road which runs from Pendra-Road to a place known as Harriott's Point, a distance of about 10 miles.

The steep ascent commences from this place and continues for nearly three miles till the plateau is reached. The topographical features of the last three or four miles are such that the construction of a railway would be very expensive and, therefore, out of the question. A better road runs from Kabir Chautra to Pendra Road but it is seven or eight miles longer than the one which runs from Pendra Road to Amarkantak.

As has been stated above, bauxite of very good quality occurs near Umergohan, Mira, and Mohodih which are, respectively, at distances of 9, 13, and 17 miles from Pendra-Road railway station if measured in a straight line. As the best quality is invariably mixed with inferior stuff, bulk samples will necessarily show a lower percentage of alumina than select samples. When mined or quarried on a large scale the bauxites of the plateau will, most probably, be found to contain from 50 to 55 per cent of alumina provided that very highly ferruginous stuff be picked out and discarded during the mining or quarrying operations. In the following table typical analyses of French, German, American, and Irish bauxites are given which should prove useful for the purpose of comparison :—

Locality.	Al_2O_3	Fe_2O_3	SiO_2	TiO_2	$CaCO_3$	H_2O
Baux (France) ..	72 61	8 2	10·0	—	—	9·0
Red Bauxite from Var (France)	65·20	21·90	0·29	3 40	—	14 10
Vochein (Germany) ..	63·06	24·55	4·15	—	—	8 34
Georgia (America) ..	57 28	0·96	9·08	3·44	—	29·12
Ireland	62·89	1·98	6·01	—	—	28·92

The above analyses show that the bauxites of Beaux contain a nearly equal amount of silica and iron. Those

from Vochein and Var show a high percentage of iron oxide and a low percentage of silica while those from Georgia and Ireland are low in iron and high in silicon. The bauxites of Amarkantak have more iron than silicon and thus resemble the red bauxite from Var.

The only other deposits of bauxite which need be considered, at present, for the manufacture of Aluminium in Rewa State are those of the Jubblepore District in the neighbourhood of Katni and Bijeraghogarh.

BAUXITE OF THE JUBBLEPORE DISTRICT.

Mr. F. R. Mallet was the first to note the occurrence of aluminous laterite at Tikari near Katni (Lat. 23° 50′ · Long. 80° 28′) in 1883. It was not till 1905, however, that the importance of aluminous laterites of Katni and of other parts of India as the principal ore of aluminium was fully realised. Messrs. H. and F. J. Warth were the first to discover in 1903 that many of the Indian laterites were, in fact, bauxites and since then the officers of the Geological Survey of India have carried on investigations in various parts of India as the result of which many new localities containing good bauxite were discovered. The alumina content of the Katni and Bijeraghogarh bauxites varies from 50 to 65 per cent as will be seen from the following analyses:—

Locality.	Al_2O_3	Fe_2O_3	H_2O	SiO_2	TiO_2	CaO	MgO
Katni. Two samples.	65·48	3·77	19·38	0·38	11·61	—	trace
(Lat. 23° 50′ · Long 80° 28′).	52·67	7·04	29·83	1·26	1·26	1·75	trace
Bijeraghogarh (24° 0′ : 80° 41′)	57·50	6·53	26·94	2·35	6·61	0·15	—
Two samples	58·23	5·48	28·10	2·01	6·49	0·45	—

The following table shows the output of Katni bauxite from 1909 to 1919 and its value in pounds sterling :—

Year	Quantity.	Value.
	Tons.	£s
1909	32	12
1910 .. .	66	25
1911 .. .	12	5
1912 .. .	950	516
1913	1,184	33
1914 . .	514	32
1915 .. .	876	29
1916 .. .	750	463
1917	1,363	620
1918	1,192	894
1919	1,682	1,934

XXXIX. A Short Account of the Processes used for the Production of Aluminium.

Before discussing the possibility of the generation of electrical energy at a sufficiently cheap rate to make the enterprise of the manufacture of aluminium in Rewa State commercially successful it would be worth while to describe the main operations necessary for the production of the metal from crude bauxite. To the genius of Humphrey Davy and Faraday may be attributed the present-day successful manufacture of a number of metals, alloys and chemical products in which electrolytic processes play a prominent rôle. Both these eminent men laid the foundation of the sciences of electrochemistry and electrometallurgy and to-day the industries depending upon one or other of these sciences have acquired vast proportions Among the substances which can be manufactured by electrochemical means aluminium holds the foremost rank.

Aluminium was first isolated from its chloride, about the year 1824, by Oersted who used potassium to decompose the salt. In 1858 Deville found a process for the preparation of aluminium on a larger scale than before. He prepared aluminium chloride by a special method and then decomposed it by means of sodium in an atmosphere of hydrogen. This process was used for the production of small quantities of aluminium for many years from 1860. These chemical processes were so costly that aluminium was quoted at Rs. 2 per lb troy in 1862.

Cowles Process.

It was not until 1886 that a process was invented to produce aluminium by the reduction of its oxide in an electric furnace on a large scale. This process in which powdered corun-

dum, charcoal, and iron filings were heated together in a large electric furnace was known as the Cowles Process from the name of its inventor. In this process the presence of iron or copper filings was found to be essential for the reduction of alumina. When copper was used, an aluminium bronze consisting of about 30 per cent of aluminium was obtained. When a mixture of powdered corundum (which is chemically equivalent to alumina) and carbon was used without the admixture of copper or iron the aluminium produced was found to be impure, as the carbon united with aluminium at the high temperature of about 2100°C. (which was necessary for the reduction of alumina) and formed a carbide of aluminium. The addition of copper or iron made the reduction of the alumina practicable at lower temperatures and the resulting alloys were found to be free from carbon. This process was not electrolytic in character, the electric current simply serving to produce the immense heat necessary for the reduction of alumina by carbon. This process was used at the Milton Works in Staffordshire. The furnace used in this operation was supplied with a current of 5,000 amperes at 60 volts from a dynamo of 300 K.W. capacity specially constructed for the reduction works.

The Hall Process

The above method was soon displaced by a very important process known as the Hall Process in which an electric current of low voltage (from 5 to 8 volts) is used to decompose an electrolyte consisting of a molten mixture of pure alumina, cryolite, and fluor-spar. The cryolite which is a double fluoride of sodium and aluminium, and fluor-spar which is a fluoride of calcium are used to enable a larger quantity of alumina to be taken into solution without the necessity of raising the temperature above 950°C. Hall's process

was first worked in America in 1888. At present the Aluminium Company of America own three large reduction works in which Hall's process is used.

Heroult Process

Heroult, a French chemist, first devoted his attention to the manufacture of copper-aluminium alloys He used neither cryolite nor calcium fluoride in the electrolyte but only fused alumina Copper was also used to enable the liberated alumina to combine with it rapidly with the formation of aluminium bronze A current of about 400 amperes was used at from 20 to 25 volts. This process was, however, soon abandoned and Heroult's process as used at the present day is identical with Hall's process. The cell used by the British Aluminium Company at Foyers in Scotland consists of a carbon-lined box in which the carbon blocks forming the anode are suspended a short distance from the bottom The carbon lining of the cell acts as the cathode Since aluminium is specifically heavier than the electrolyte when in the fused state, it forms a pool of molten metal on the bottom and can be ladled out or siphoned off from time to time. Voltages of from 5 to 8 are used, and the strength of the current varies from 8,000–10,000 amperes in small units and from 15,000–20,000 amperes in large size furnaces. Heroult's process is used at Saussay in France, Neuhausen and Rheinfelden in Switzerland, and Bergheim in Germany. Practically the whole of the world's output of aluminium is at the present day obtained by the Hall and Heroult processes.

PREPARATION OF PURE ALUMINA.

Having described the different processes for the manufacture of aluminium we shall now proceed to describe the methods at present followed for the preparation of

alumina on the purity of which the success of the reduction processes mostly depends. The method which is almost universally employed at the present day is known as the Bayer's process or the "Wet" process The first operation consists in calcining the bauxite at a temperature of about 400°C. by which organic matter is destroyed, moisture is driven off, and the iron is converted into ferric oxide. The calcined bauxite is crushed and very finely ground, and then treated with a solution of caustic soda having a specific gravity of about 1·45. The mixture is then transferred to specially constructed digesters where it is subjected to a pressure of from 50 to 70 lb per square inch and heated by means of steam which circulates in the jackets fitted to the autoclaves. The alumina of the bauxite is converted into soluble sodium aluminate while iron and titanium hydrates and other impurities are precipitated. The mixture is then blown out into large tanks, stirred, heated, and diluted with hot water and the washings from previous filtrations, and is then filtered. The clear liquid is allowed to stand in large tall tanks for about a week, and aluminium hydroxide from previous operations added to it, from time to time, during this period. By this method about two-thirds of aluminium hydrate is precipitated which is afterwards separated off in filter presses. The amorphous aluminium hydrate is next calcined at a temperature of about 1000°C. by which the water of hydration is removed, the resulting product being crystalline alumina. The crystalline form of alumina is the most suitable one for storage or transport as it absorbs very little moisture.

Other processes.

There are other processes which differ from the Bayer process chiefly in the salt used to convert the bauxite into sodium alu-

minate In one method sodium carbonate is used. This is known as the " dry soda " process. In another, sodium sulphate is used, the method being known as Peniakoff process. There is still another method in which calcined and powdered bauxite is treated with an excess of sulphuric acid whereby the iron goes into solution and sulphate of aluminium crystallises out.

Serpek process.

There is one more process which deserves special mention. It is the Serpek process which is being developed in France. The importance of this process lies in the fact that in one operation it yields both alumina and compounds of nitrogen. In this process bauxite is first calcined in a kiln and mixed with carbon The mixture is then fed in a second kiln where it passes through an electric furnace of the resistance type which raises its temperature from 1800-1900° C. At the same time, the mixture has to encounter a large stream of nitrogen and carbonic oxide supplied by a gas producer By this means the alumina of the bauxite is rapidly converted to aluminium nitride. The arrangement of the kilns is very ingenious, one of the kilns being on the top of the other In the top kiln, the bauxite meets with the waste gases from the lower kiln. The calcined bauxite discharges itself into a hopper in which carbon is also fed and the mixture is then introduced in the lower kiln. The aluminium nitride formed in the above process is treated with a solution of caustic soda by which ammonia and sodium aluminate are formed Insoluble matter is then filtered off and to the clear filtrate some aluminium hydroxide is added which has the effect of precipitating more aluminium hydrate which is filtered off and calcined as in the Bayer process.

Having given a brief account of the various processes

employed in the manufacture of alumina and in its reduction we shall now describe the three power schemes which the writer has in view for the generation of power in Rewa State.

XL. Power Schemes in Rewa State.

For the manufacture of alumina and for its reduction one of the chief essentials is cheap power. For the generation of power on a large scale the writer has in view three different schemes:—

1. Generation of power by large turbo-alternators of the most approved design, the turbines to be operated by high pressure, superheated steam

2. Generation of power by a hydro-electric plant, the necessary water to be obtained from the rivers Tons or Tamas and Beehar at places known as Poorwa and Chachai on the edge of the Rewa plateau where the water falls in a great sheet about 600 feet broad and 370 feet high.

3. Generation of power by a hydro-electric plant, the necessary water to be obtained by the creation of artificial lakes in suitable places on the Maikala Hill range within Rewa territory.

1. The writer's suggestion for the generation of power on a very large scale through the medium of steam turbines will probably be received with a certain amount of incredulity in some quarters as it is common knowledge that the cheapest power could only be produced by the natural hydraulic resources of any country. However, it should be remembered that ideal conditions for utilizing natural water power exist only in a few cases in the whole of India. In the majority of cases the construction of artificial lakes would be found essential. The construction of large dams for storing water and of long pipe-lines for conducting it to suitable places would entail a lot of preliminary expenditure. Then again it rarely happens that

suitable sites for the generation of hydro-electric power are close to the spot where the power is actually required and in many cases long lines for the transmission of power are necessary. These factors make the utilization of water power less simple than it appears It is true that almost all large electrochemical and electrometallurgical works in America and Europe are supplied with the necessary electric current from large hydro-electric plants but there is no reason to suppose that coal would not be used for the generation of power on a large scale in those countries if its production was as cheap there, as it is in India. On some of the Indian coal-fields, at present, the cost of raising one ton of coal amounts to from Rs. 3 to Rs. 4 per ton while the pit-mouth cost of coal on the English collieries at the present day amounts to from Rs. 15 to Rs. 20 per ton. Again in England and other countries the demand for coal is so great and the prices realised so high that it would not be possible, even for a combination of collieries to supply electric power on a large scale, at a cheap rate, to electrochemical works. In India there are vast coal-fields which have not yet been developed. Such coal-fields could very well be utilised for the production of power on a large scale. The coal appears in many cases very near the surface; labour is cheap; royalty charges are not prohibitive All these tend to cheapen production.

Having made these general remarks we shall now deal with the specific case of the production of power in Rewa State on a very large scale sufficient to meet the demands of large electrochemical works by utilising the immense quantity of coal available in many of its coal-fields.

REWA STATE COAL-FIELDS.

Nature has allotted a generous share of coal-bearing formations to the Rewa State. The total area of the different coal-fields of the Rewa State is more than 2,100 square miles which compared to the total area of the State territory, viz. 13,000 square miles, is by no means small. There are, in all, five coal-fields—Umaria, Korar, Johilla, Sohagpur, and Singrauli. Of these, the first three are small, having a total superficial extent of about 30 square miles. The Sohagpur coal-field has an area of about 1,200 square miles and the Singrauli coal-field has an area of about 900 square miles All these coal-fields have been lying dormant, with the exception of the Umaria coal-field which was first opened out in 1884. For about six years the Umaria Colliery (now known as the Rewa State Colliery) was under the Government of India who handed it over to the Rewa Durbar in a flourishing condition in 1900 and since then it has been a source of considerable revenue to the State. From 1884 to 1920 the Umaria Colliery produced 4,778,230 tons of coal. The average quantity of coal raised during the five years from 1916 to 1920 was 182,773 tons per annum. The coal-fields with which we are concerned at present are the Johilla and Sohagpur coal-fields which lie to the S.E. of Umaria at distances of about 15 and 40 miles respectively.

Sohagpur coal-field.

The Sohagpur coal-field stretches through one degree of longitude from 81° 14′ to 82° 16′, a distance of about 64 miles. In a north to south direction the extent is about 30 miles. The northern and southern limits of the coal-field are fixed by latitudes 23° 37′ and 23° 4′ respectively. The Katni Bilaspur branch line of the B.N. Ry. runs for more than 30 miles in the southern part of this coal-field. Since the

last two or three years some activity is manifest near Burhar railway station on this line. At present, coal is produced from large quarries. The thickness of the seam is about 27 feet in one particular part near Dhanpuri (23° 12′ : 81° 37′). In other parts the thickness of the seams has been found to vary from 4 to 8 feet. Plots measuring about 5 square miles have been leased out by the State near Burhar railway station. There are, still, many productive areas available not far from the railway line The quality of the coal varies in different parts but on an average a calorific value of 5,500 may be safely reckoned. The following table gives the average calorific values of different samples of coal from various outcrops not far from the railway line:—

Locality.	Calorific value.
Bageha Nadi Outcrop— No 1. (23° 31′ · 81° 37′)	6,050
Bageha Nadi Outcrop— No. 2 (23° 13′ : 81° 38′) .	5,555
Sone River Outcrop— No. 1. (23° 13′ · 81° 39′) .	5,610
Sone River Outcrop— No. 2 (23° 13′ : 81° 41′) ..	6,022
Jamunia Nadi Outcrop— (23° 13′ : 81° 42′) ..	6,390
Outcrop near Semra— (23° 15′ : 81° 34′) ..	6,225
Dhanpuri Coal— (23° 11′ . 81° 36′) ..	5,665

The Johilla coal-field.

The Johilla coal-field, although small, deserves special mention owing to its proximity to the railway line, good quality of its coal, and easily accessible seams measuring about 17 feet and 6 feet. The main outcrops of coal are close to the Bir-

Singpur Railway Station on the B N. Railway. The coal-bearing formations have an area of about 11 square miles. Boring operations which were undertaken in 1882 under the direction of Mr. T. W H. Hughes revealed in one place the presence of two seams of coal 17 feet and 6 feet thick at depths of 6 and 42 feet, respectively. In another place, a boring showed the occurrence of three seams of coal 17 3, and 8 feet thick at depths of 34, 53, and 61 feet, respectively. According to Mr Hughes there are at least one hundred millions tons of coal available in this coal-field within a depth of 500 feet.

Quantity available in the Sohagpur coal-field

The total quantity of coal available in the Sohagpur coal-field is immense There is enough coal in this field to meet ordinary demands for many centuries.

ESTIMATE OF THE QUANTITY OF FUEL REQUIRED AND ITS COST.

Having given a fair idea of the extent of the Sohagpur and Johilla coal-fields, their easy accessibility, the quality of coal, and the quantity available we shall now examine the question of the cost of fuel per ton and the quantity required for producing one ton of aluminium. The scheme of generating the necessary electric current for the manufacture of aluminium by means of large size steam turbo-alternators would surely succeed if the coal were mined by the same company who undertook to produce alumina from the bauxite and reduce it to the metal. In the opinion of the writer all the three operations, namely, mining of coal, preparation of alumina, and manufacture of aluminium should be conducted by a large and powerful syndicate. It would be advisable to have the three concerns separately managed but the joint owner-

ship is, however, absolutely essential. This scheme would not be worth considering if coal had to be purchased from an outside source Even supposing that the cost of production of coal was as low as Rs. 3-8 per ton it would not be possible to get it from an outside company for less than Rs. 4-8 per ton. Thus, there would be a loss to the company of one rupee for every ton of coal consumed at the power station. The current necessary to produce one ton of aluminium would require for its generation from 25 to 33 tons of Sohagpur or Johilla coal. If it was desired to produce say 6,000 tons of aluminium per annum the total quantity of fuel required for the reduction process alone would be from 150,000 to 198,000 tons If the coal were therefore, produced by the same syndicate which proposed to prepare aluminium there would be a saving of from Rs. 1,50,000 to Rs. 1,98,000 per year.

For the production of 1 lb of aluminium the amount of electrical energy required is estimated at from 12–15 E.H.P. hours. Taking the first figure we find that the current required for the production of 1 lb of aluminium is about 9 kw. hours. For the production of 1 ton of aluminium about 20,000 units would therefore, be required In large electric power plants the consumption of good quality English coal averages about 2 lb per kw. hour. As the Sohagpur and Johilla coals have a low calorific value (about 5,500 calorics; or 9,900 B.T.U.) we shall take the coal consumption to be about 3 lb per kw. hour. As 20,000 kw. hours are required to produce 1 ton of aluminium the coal consumption would amount to about 27 tons.

The actual cost of raising one ton of coal may vary from Rs. 3-4–Rs. 4 per ton. The principal factors consist of labour charges, and rent and royalty charges. Labour is

cheap and plentiful in the Sohagpur and Bandogarh Tehsils of the Rewa State in which the Sohagpur and Johilla coal-fields are situated. Royalty on coal has been fixed by the Rewa State at 6 annas per ton and it is probable that by proper representation this figure might be reduced by the State, specially, if a very large output was guaranteed and if the fuel was required chiefly for a large electric plant. The following table shows the various items of expenditure and the average charges per ton of coal under each head :—

Particulars.	Average cost per ton.		
	Rs.	A	P
General Establishment charges	0	7	6
Royalty . .	0	6	0
Sinking fund charges . .	0	8	0
Wages for Hewing . .	0	11	6
,, ,, Tramming . .	0	5	6
,, ,, Underground labour	0	3	0
Stores . . .	0	6	6
Coal consumed at Colliery . .	0	3	0
Workshop charges .	0	2	0
Engine and Boiler House Establishment	0	1	0
Repairs . . .	0	3	6
Medical charges . .	0	0	6
Audit charges . . .	0	0	3
Total .	3	10	3

The above figures are only approximate, and simply serve to show the distribution of cost per ton of coal in a colliery having an output of about 175,000 tons per annum.

XLI. Cost of Materials used in the Manufacture of Aluminium.

Under this head we shall deal with materials used in the preparation of alumina and in the reduction process. Regarding alumina, it may be stated that it can be produced at about Rs. 119 per ton, from Amarkantak or Katni bauxites, provided that the plant for calcining, crushing, grinding, and lixiviating the bauxite with caustic soda be erected on the Sohagpur coal-field close to the Burhar Railway Station on the Katni Bilaspur line of the B N. Railway. The advantage of this situation is evident enough For the various mechanical operations involved in the preparation of alumina from bauxite cheap fuel would be of prime importance The distance from Burhar to Pendra-Road is about 45 miles and that between Pendra-Road and Amarkantak about 15 miles. The distance from Katni to Burhar is about 95 miles. The distance to which the bauxite would therefore, have to be railed either from Pendra-Road railway station or from Katni, to Burhar, is not very great and whatever additional expense would have to be paid in freight would be more than compensated for, by the cheap power available not only for the crushing, grinding, calcining, and heating operations employed in the preparation of alumina but also for its reduction in electric furnaces.

In the preparation of alumina from bauxite the chief material required is caustic soda. Although this chemical plays an important part in the process it is not actually used up and, practically, the whole of it is recoverable, the losses being due to mechanical waste only. To compensate for this, small quantities of caustic soda are

added from time to time. The chief materials required in the manufacture of alumina are, therefore, bauxite of good quality and caustic soda A plant for preparing alumina would have to be fitted up with crushers, pulverisers, autoclaves, screening machines, filter-presses, etc. A certain amount of skilled labour and efficient supervision would be necessary.

For the production of one ton of pure alumina 2–2½ tons of bauxite are required In the reduction process two tons of alumina yield one ton of aluminium. For every ton of aluminium produced, 4 to 5 tons of bauxite would, therefore, have to be used. For a plant having an output of 6,000 tons of aluminium per annum, 24,000–30,000 tons of bauxite would therefore be required. This would yield about 12,000 tons of pure alumina. Taking into consideration mining costs, freight, charges of labour, supervision, power, and interest and depreciation the total cost of producing one ton of alumina at Burhar would be Rs. 119 per ton. If the department for the preparation of alumina were conducted separately, it would be quite possible for such a concern to supply pure alumina to the reduction works at Rs. 150 per ton, at the same time making a profit of Rs. 31 per ton or an annual profit of Rs. 3,72,000 if the alumina plant had an output of 12,000 tons per year.

For the reduction of alumina, fluxes would have to be replenished from time to time, and the carbon electrodes would have to be renewed as those in use get consumed in the process. Both these are costly items. The fluxes commonly used are cryolite and fluor-spar. The former occurs in large quantities in Greenland. It is also prepared artificially from sodium alum and hydrofluoric acid and answers the purpose for which the natural product is

used, quite satisfactorily. It is, however, more readily decomposed than natural cryolite and, therefore, larger quantities have to be used. Fluor-spar or calcium fluoride occurs abundantly in Cumberland and Derbyshire in the north of England, and in Cornwall Neither cryolite nor fluor-spar have been found to occur in large quantities in India and both these minerals would therefore, have to be ordered from abroad. The specimens of fluor-spar so far obtained in India occur in small veins in gneisses and schists and are of no economic importance whatsoever.

The consumption of carbon electrodes has been computed to average 1 lb. for every pound of aluminium produced, when the electric furnace is working very satisfactorily. According to the following equation the consumption of carbon should theoretically equal 36 lb for 54 lb of aluminium produced:—

(*a*) $Al_2O_3+3C=Al_2+3CO$.

(*b*) $102+36=54+84$.

Equation *b* is obtained by substituting the chemical symbols by their atomic values.

In practice, it is not possible to reduce the consumption to less than 1 lb of carbon for 1 lb of aluminium produced and to ensure this result also, the greatest care and judgment have to be exercised; otherwise larger amounts of carbon are consumed. The manufacture of carbon electrodes requires great care in manipulation as a number of conditions must be fulfilled by them before they can be employed satisfactorily. The purity of the carbon used is of the greatest importance as otherwise there is danger of the metal being contaminated. The anodes have to satisfy certain other conditions also regarding resistance, conductivity, homogeneity, density, and freedom from cracking or "waist" during operation. They are

now generally made of petroleum coke which yields $\frac{1}{2}$–$2\frac{1}{2}$ per cent ash only. As the manufacture of electrodes requires a lot of care and experience it would, at first, be best to leave it to firms who have made a speciality of this branch of industry. The market price of carbon electrodes of good quality in the United Kingdom is about £15 per ton.

The following estimate shows approximately the cost per ton of alumina :—

Particulars.	Cost		
	Rs.	A.	P.
Cost of mining $2\frac{1}{2}$ tons of bauxite at Rs 4 per ton	10	0	0
Aerial ropeway charges on $2\frac{1}{2}$ tons of bauxite (from Amarkantak to Pendra-Road) including interest and depreciation on capital charges	12	0	0
Approximate railway freight on $2\frac{1}{2}$ tons of bauxite from Pendra-Road to Burhai	2	12	0
Rent and royalty charges ..	1	4	0
Labour and supervision ..	7	8	0
Power charges, and coal for kiln ..	10	0	0
Caustic soda, about $1\frac{1}{2}$ cwt. ..	40	0	0
Interest and depreciation ..	25	0	0
Stores and repairs	7	8	0
Office expenses and establishment	3	0	0
Total ..	119	0	0

The above is an estimate of cost per ton of alumina in a plant capable of producing 12,500 tons of alumina per annum. It is a liberal estimate as will be seen by examining the various items in detail :—

(*a*) *Cost of Mining Bauxite.*—It may be possible to

reduce the amount from Rs. 4 to Rs. 3 per ton. At present, in the Sohagpur coal-field at a place known as Dhanpuri, coal is being supplied by contractors to the Baghelkhand Mining Syndicate at Rs. 2-4 per ton. Judging by analogy the cost of quarrying bauxite should not be very great. Of course, much depends on the overburden which may have to be removed. However, Rs. 4 per ton will be found to be quite sufficient.

In many works on the continent of Europe it has been found that two tons of bauxite yield one ton of alumina. In the above estimate it has been assumed that 2½ tons of bauxite would be required to produce 1 ton of alumina, the reason being that the amount of combined water contained in the Amarkantak and Katni bauxites is higher than in the French and German bauxites.

In the estimate, the price of Amarkantak bauxite only is given. If it was found necessary to use Katni bauxite it would be quite feasible to do so. This bauxite could be obtained at from Rs. 5 to Rs. 7 per ton loaded in wagons at Katni-Murwara station. The distance between Katni and Burhar is 90 miles, that is, about double the distance between Burhar and Pendra-Road stations (44 miles). The railway freight on 2½ tons of Katni bauxite would be approximately Rs. 5-8. There being no ropeway or tramway charges on the Katni bauxite it would be cheaper to use it at first but it is quite likely that the price would reach the higher figure of Rs. 7 per ton as more and more of it was required. On the other hand there is a likelihood of mining cost being reduced from Rs. 4 to Rs. 3 per ton in the case of the Amarkantak bauxite. It may also be possible to reduce the ropeway charges from Rs. 12 to Rs. 10 for 2½ tons of bauxite carried from Amarkantak to Pendra-Road railway station. In the opinion of the

writer it would be safest to have mining rights over both the deposits and to open out both of them.

(*b*) *Charge for Transport by Aerial Ropeway.*—The estimate given under this head is also quite reasonable. The ropeway would be required to have a carrying capacity of 10 tons per hour. If it was worked for 10 hours a day the total quantity carried in one day would be 100 tons. If we take the number of working days in a year to be 300 the ropeway would transport 30,000 tons of bauxite during one year which quantity would be sufficient for an aluminium reduction works having a capacity of producing 6,000 tons of aluminium per annum.

Aerial ropeways cost from Rs. 25,000 to Rs. 40,000 per mile according to the gradient, span, and loading capacity of the plant. In the estimate given above, the higher figure is used and interest and depreciation is allowed on the capital charge reckoned at this rate. In the beginning it would be advisable to have a ropeway from Pendra-Road railway station to Amarkantak and then to connect up the latter with Umergohan and other places as development progressed. The distance between Amarkantak and Pendra-Road, as the crow flies, is 11 miles and that from Umergohan to Pendra-Road is 9 miles. In practice, it will be found easier to connect Amarkantak with Pendra-Road.

(*c*) The railway freight from Pendra-Road to Burhar is calculated on the basis of 8 annas, per mile, per wagon. The distance between the two places is 44 miles.

(*d*) *Rent and Royalty.*—Although no rate has yet been fixed by the Rewa Durbar for royalty on bauxite, that given in the estimate, viz. Re. 1-4 for 2½ tons of bauxite is quite reasonable and is not likely to be enhanced.

(*e*) *Caustic Soda.*—As has been said before, very little

soda is consumed in the process of manufacture of alumina. The loss is chiefly due to mechanical waste only. If, however, the ore is siliceous part of it would be consumed and it is, therefore, necessary to correct this tendency by the addition of a small quantity of lime which converts the silica into calcium silicate. The Amarkantak and Katni bauxites, both, contain only a small proportion of silica and very little loss of caustic soda should therefore occur. In the estimate, 1½ cwt. of caustic soda is allowed for 2½ tons of bauxite to replace the quantity lost in the various mechanical operations.

(*f*) *Capital Charge.*—The capital charge for an alumina plant capable of producing 12,000 tons of calcined alumina has been reckoned at Rs. 30,00,000 including railway siding, buildings, etc., but excluding the aerial ropeway for which separate provision has been made. Depreciation and interest has been allowed on this sum at the rate of 10 per cent.

(*g*) *Other Charges.*—Charges for stores, repairs, labour, supervision, office expenses, power, and coal for rotary kilns, shown in the estimate, will be found to be adequate enough.

The total cost of one ton of alumina is Rs. 119 according to the estimate. We will suppose that it is delivered to the reduction works at Rs. 150. The net profit per ton would, therefore, be Rs. 31, i.e. a total profit of Rs. 3,72,000 per annum thus giving a return of more than 12 per cent on the capital charges.

The present market value of calcined alumina in Europe is very high ranging from £20 to £30 per ton. At this rate it would be highly profitable to export the prepared alumina to England and other places in Europe. To meet the extra demand a larger plant would have to

be erected. A large output would conduce to a lowering of the working costs Whether the alumina is used for internal consumption, or for export to foreign countries, or for both these purposes there is no doubt that there is a great future for this industry.

XLII. Factors which Govern the Cost of Aluminium.

Power required

Various estimates place the amount of electrical energy required, at, from 12–16 E H.P. hours per pound of aluminium. This is far in excess of the energy which would be theoretically required. The reason for this is obvious enough A well constructed furnace when working properly has an efficiency of 90–95 per cent. Ordinarily, however, the efficiency varies from 50 to 85 per cent due to mishaps during operation, change of furnaces, etc. According to Pattison, (see "Aluminium" by J. T. Pattison, 1918, p. 12) at the Pittsburg Co.'s reduction works the yield of each furnace consuming about 10,000 amperes at 5·5 volts was 1 75 lb of aluminium per horse-power day. This result was arrived at some years ago It is very likely that with recent improvements in furnace construction the efficiency may have increased still more. However, assuming that 1·75 lb of aluminium would be produced per horse-power day, about 23,000 kw.-hours would be required for one ton of aluminium. Large turbo-generators consume 2 lb of good English coal per kw.-hour. In our scheme of generating power, Sohagpur coal would be used the calorific value of which is, approximately, 5,500 calorics. The coal consumption would, therefore, be nearly 3 lb per kw.-hour or about 31 tons, per ton of aluminium produced.

Total capacity of the Generators required.

Taking the number of working days in a year to be 300, it would be necessary to produce 20 tons of aluminium daily. If the furnaces were worked continuously, i.e. for full 24 hours of the day it would be necessary to have electrical energy sufficient to produce $\frac{5}{6}$ ton of aluminium,

per hour. In practice it would be impossible to keep all the furnaces running continuously for 24 hours of the day. Provision must therefore be made for electric power capable of producing nearly double the quantity of aluminium, i.e. about 1½ tons per hour. This would require electrical energy equivalent to 34,500 kw.-hours. It is possible to produce the whole of this output by a single large unit (which would be cheaper than 4 or 5 units having the same aggregate output) but it would not be wise to do so because if any mishap happened either to the turbine or the generator the output would suffer considerably. There is, of course, one thing which could be said in favour of a very large turbo-generator, viz. a low fuel consumption, but the corresponding disadvantage in this particular case would be greater. It would be best to have 4 units with a total output of 34,500 kw. and an auxiliary unit to take the place of any one of the others in case some urgent repairs were required to one or other of them. This would bring the total capacity of the power-plant to 42,000 kw.

Cost of Power-plant and Reduction-Works.

The cost of a plant including five turbo-generator sets with an aggregate capacity of 42,000 kilowatts, boilers, condensers, etc., etc., would be Rs. 94,50,000 at the rate of £15 per kilowatt. Furnaces, buildings, railway siding, workshop tools and machines, residential quarters for employees, etc., would mean about 30 lakhs of rupees. The total capital investment required would therefore be 1¼ crores of rupees.

Alumina.

The question of alumina has already been dealt with and we have seen that the Alumina Works could deliver it at Rs. 150 per ton thereby making a profit of Rs. 31 per ton. As two

tons of alumina are required to produce one ton of aluminium the cost of alumina will be Rs. 300.

Cryolite and fluxes

The consumption of cryolite and fluxes has been found to be ¼ ton, per ton of alumina produced. We will here suppose that a mixture of 400 lb of cryolite and 160 lb of fluor-spar would be necessary. According to Mr. C. S. Fox (who has written an admirable article on the bauxite resources of India in the February issue of the *Mining Magazine* pp. 82–96) the present market price of cryolite in the United Kingdom is £56 per ton. This seems to be considerably in excess of the price at which cryolite is imported in the United States from Greenland. In the pamphlet on aluminium and bauxite (1913–1919) published by the Imperial Mineral Resources Bureau the value of 2,130 long tons of cryolite imported in the United States in 1919 was £22,283 which is approximately equal to £10½ per ton. For 1914 the value of cryolite imported there was about £4.

Clinton P. Bernard who wrote an article on the cryolite mine at Ivigtut in Greenland, in 1916, in the April issue of the *Mining Magazine* states—"In mining two grades are recognized, the 'white' and the 'black.' The white contains about 90% to 95% cryolite, the remainder being pyrite, galena, and siderite. Mineral of this description is shipped to Copenhagen. The black contains, besides the above impurities, a large amount of fluorite. This grade is shipped to Philadelphia and is valued at about 20 dollars per ton." According to this statement also the price of cryolite was £4 per ton in 1916 in the United States. For the 'white' cryolite the price at that time may have been £7 to £10 per ton. It is, therefore difficult to understand why the market price in the United

Kingdom is £56 per ton, at present. However, if we take this rate to be correct, the cost for 400 lb of cryolite would be Rs. 150. The cost of 160 lb of good fluor-spar would be approximately Rs. 30. Allowing for sea-freight, railway freight, dock dues, etc , etc., the cost of fluxes would be Rs. 250 per ton of aluminium produced.

Carbon electrodes

The consumption of carbon electrodes varies from 1 lb to 3 lb and more, per pound of aluminium produced It has been stated that the consumption of anodes may, with care, be reduced to 1 lb for every pound of aluminium produced. We will assume that the consumption of electrodes would be $1\frac{1}{2}$ tons for every ton of aluminium produced. The price of electrodes of good quality during the war period and soon after was £15 per ton. It may be possible to get large quantities at a lower rate, at present. However, at £15 per ton the price of $1\frac{1}{2}$ tons of electrodes would be Rs. 337-8. Allowing for sea freight, railway freight, dock dues, etc., it should be possible to get them for Rs. 460 at the proposed site at Burhar. The carbon electrodes form the costliest item in the whole list and it would be worth while to make the electrodes in India as soon as the industry is well under weigh.

Coal.

This subject has already been discussed. It should be possible to get coal at Rs. 5 per ton. As 31 tons of coal would be required for every ton of aluminium produced, the cost of coal per ton of aluminium would be Rs. 155.

Interest and depreciation, labour, supervision, etc.

Interest and depreciation have been reckoned at 10 per cent on the probable capital outlay of $1\frac{1}{4}$ crores of rupees. The other charges regarding labour, supervision, stores, repairs, agents' commission, and

office expenses have been carefully thought out and should prove quite sufficient.

The following estimate shows approximately the probable cost per ton of aluminium :—

Particulars.	Cost.		
	Rs.	A.	P.
2 tons of alumina	300	0	0
Fluxes (cryolite and fluor-spar) ¼ ton	250	0	0
Carbon electrodes 1½ tons .	460	0	0
Coal for power plant (31 tons) ..	155	0	0
Interest and depreciation ..	209	0	0
Labour and supervision ..	15	0	0
Stores and repairs.. ..	25	0	0
Office expenses .	15	0	0
Agent's commission, director's fees, etc.	30	0	0
Total ..	1,459	0	0

Profit.

Aluminium is variously quoted in the Indian markets at from Rs. 100 to Rs. 135, per cwt., at present. According to the estimate given above, the cost per ton would be Rs. 1,459. Taking the lowest current market value of good quality aluminium at Rs. 2,000 per ton, this would leave a net profit of Rs. 541 per ton or a return of 25 % on the capital investment. The price of this metal may go down, but it must be remembered that a fall in the price of aluminium will be invariably attended by a fall in the price of other articles. The cost of electrodes is the heaviest in the whole list and means would have to be devised to reduce their consumption. It would be found necessary to utilize the rejected stumps or unused ends by crushing and

gristing them and manufacturing new electrodes from the powder thus obtained by mixing it with hot tar and then moulding it in a hydraulic press under a pressure of one ton to the square inch.

Concluding remarks

All the three estimates—those showing the cost per ton of coal, alumina, and aluminium—are very liberal. For instance the estimate regarding the cost per ton of coal is stretched to its utmost limit. It is very likely that in a colliery producing from 175,000 to 190,000 tons of coal, per year, the cost per ton would be somewhat less with proper management than that shown in the estimate This is not merely a matter of conjecture but of careful study of the figures showing the cost per ton of coal produced by the Rewa State Collieries at Umaria from 1884 to 1921. Up to 1917, the cost per ton was less than Rs. 3 per ton. Recently, the cost has shown a tendency to rise but it is quite probable that, with the return of normal conditions, the cost may again go down.

The following table shows the imports of aluminium in British India during the last nine official years (April to March). These figures were kindly supplied by the Director of Statistics to whom the writer wishes to acknowledge his indebtedness. It will be seen from the figures that the demand for aluminium in India was at its highest in 1920–21.

IMPORTS OF ALUMINIUM INTO BRITISH INDIA.

Official year (April to March)	Quantity. cwt	Value £.
1912–13 .	35,809	170,097
1913–14 .	26,347	142,528
1914–15 ..	15,550	87,046
1915–16	15 434	95,333
1916–17	823	12,290
1917–18 .	731	15,028
1918–19 ..	11,639	149,213
1919–20 ..	23,184	253 498
1920–21 ..	62,637	876,541

Value figures for 1919–20 and 1920–21 have been converted at the rate of Rs. 10 = £1 and at Rs. 15 = £1 for earlier years.

The following table shows the prices of aluminium in the United Kingdom from 1913 to 1919:—

PRICES OF ALUMINIUM IN THE UNITED KINGDOM.

Year.	Lowest. £ per ton	Highest. £ per ton.
1913 .	81	85
1914 ..	81	100
1915 ..	100	160
1916 ..	150	150
1917 ..	225	225
1918 ..	200	225
1919 ..	150	200

This table has been copied from the bulletin on Aluminium and Bauxite recently published by the Imperial Mineral Resources Bureau.

Before the war, and for a few months after its commencement, the largest supplies of aluminium came into India from Germany. In 1913, '14, and '15 the quantities imported from Germany were 956, 607, and 301 tons respectively. During the same period, United States supplied 415, 179, and 135 tons respectively, while Belgium supplied 73, 39, and 41 tons. In 1916, India imported 301 tons from the United States, 10 tons from Japan, and 7 tons from the United Kingdom. In 1917 and '18 the total imports of aluminium into India fell considerably. In 1919, Japan was the chief supplier. In that year, 383 tons were imported into India from Japan and 135 tons from United States.

XLIII. Scheme of Generating Power from the Waters of the Tons and the Beehar Rivers near Poorwa and Chachai on the edge of the Rewa Plateau.

The river Tons otherwise known as Tamas (also Parnās of the Purānās and Rāmāyan, and the Prinās of Megasthenes) rises at Jukehi in the Maihar State. The nominal source of this river is the Tamas Kund which is a tank situated on the Kaimur range at an altitude of about 2,000 feet above sea-level. From this point the river takes a N.N.E. course and after winding its way foı about 100 miles falls over the plateau about a mile to the S.E. of Poorwa (24° 47′ . 81° 19′). Its principal affluent is the Sutna River, the union taking place at a point about 2 miles to the south of the Sutna railway station. The Beehar has its source near Mouhwas (24° 13′ : 81° 2′) in the Kaimur range. For the first 25 miles of its career it collects all the water from the watershed area of the north of Kaimur range between Kerahi and Govindgurh. Near Rewa (24° 32′ · 81° 20′) the Beehar meets with Bichia Nadi which has its source near Chupra (24° 33′ : 81° 45′). This river collects all the water from the watershed area east of Govindgurh for 30 miles. Thus, the combined waters of the Beehar and Bichia contain all the water collected from the northern watershed of the Kaimur range for a length of 50 miles.

Both the Beehar and the Tons fall over the edge of the plateau deep down on to the rocky channels beneath. The fall of the Beehar rivals in magnitude that of the Tons. Both present a grand spectacle towards the close of the rainy season. The Beehar precipitates itself off the plateau in a great sheet of water 600 feet broad and 368

feet high. The sheer fall of the Tons is much smaller being only 193 feet in height, another 140 feet being gained between the fall and the junction of the Beehar. After falling over the plateau the Tons flows through a narrow gorge for about 4 miles and meets the Beehar in Lat. 24° 48′ : Long 81° 21′ From this point the combined waters of the two rivers flow for nearly 6½ miles in a narrow valley formed by precipitous hills on both sides and then enter the plains below.

Keonti waterfall

Besides the two waterfalls mentioned above there is another about 10 miles to the east of Chachai near Keonti (24° 48′ : 81° 30′) about a mile to the north-east of Balehra. At this spot the waters of the Maha River fall from the plateau on to the rocky channel beneath. The actual fall is 275 feet but in the rapids above the stream there is a fall of 65 feet from the normal bed level to the top of the fall. The force of the water falling from this great height has hollowed out the rock below and turned it into a pool (Kund). The escaping water flows for more than two miles down a canon with overhanging cliffs on either side. The volume of water which falls over the plateau is small in comparison with the waters of the Tons and the Beehar.

Value of the three falls as sources of power.

The possibilities of generating power seem to be most promising. The commercial value of the Tons, Beehar, and Keonti waterfalls had been recognised many years ago but owing to there being no great demand either in Rewa State or in adjoining parts the question had never been considered seriously. Recently, the Government of India decided to conduct a systematic survey of the water-power resources of the whole of India, for the generation of electric power. In accordance with

16

this scheme, the water-power sites near Tons, Beehar, and Keonti had been visited by the officers of the Hydro-Electric Survey of India. A preliminary survey had been made by Mr C. W. Lacey, Assistant Engineer, Ken Canal Division, in April 1920. Mr. F E. Bull, Chief Engineer, Hydro Electric Survey of India, visited all the power sites in Rewa State in January 1921. The figures given below regarding the discharge of water, capacity of reservoirs, probable height of bunds, area submerged, and cost of reservoirs have been taken mostly from Mr. Bull's " Inspection Notes"

Tons waterfall

The catchment area of the Tons River above the fall is about 2,000 square miles The discharge of the river was measured by the staff of Hydro-Electric Survey of India and found to be 100 cusecs in December 1920, and 47 cusecs in May 1920. The average rainfall in the Raghurajnagar Tehsil is 41 inches. It has been ascertained that with a bund 80 to 90 feet high, 50,000 to 60,000 million cubic feet of water could be impounded. The total fall which could be utilized is, as stated above, about 333 feet. The quantity of earth required for the bund will probably be from 12 to 18 crores of cubic feet. The cost estimated by Mr. Bull for bund, escape, buildings, and compensation for land is one crore of rupees. No estimate has yet been made for pipe-line, machinery, and transmission-line. The available power is 36,000 to 56,000 E.H.P.

Beehar waterfall near Chachai.

The catchment area of the Beehar River above the fall is 640 square miles. The height of the fall is 370 feet and an extra 50 to 90 feet of head could be gained between the fall and its junction with the Tons. It is estimated that some 14,000 million cubic feet of water

could be stored. The power generated on a 420-foot fall would be 14,000 E.H.P. This scheme has not yet been surveyed and worked out in such detail as the Tons-Valley power scheme.

Maha River waterfall near Keonti

The Maha River which is a tributary of the Tons has a catchment area of 380 square miles above the fall. The vertical fall is 275 feet and an additional 75 feet can be obtained in the bed of the river There is a suitable site for the power house 2 miles below the fall. Regarding the discharge there is some difference of opinion. The maximum estimate is 48 cusecs in winter and 17 cusecs in summer. The storage capacity is about 2,000 million cubic feet with a bund 60 to 70 feet high. The land above the fall is good and culturable How much of it would be submerged has not yet been computed. An unmetalled road runs from Rewa straight up to Keonti and further towards Sitlaha The power available is 7,000 E.H.P.

Total power available

Thus, we see that the three water-falls of the Tons, Beehar, and Maha Rivers could be made to generate from 57 to 77,000 E H.P. by impounding their waters in large reservoirs.

Demand for power

There is very little demand at present for electric power in Rewa and there is not likely to be a large demand in the near future except it be for an aluminium reduction works. Large cities like Allahabad, Jubblepore and Cawnpore are at distances of 70, 125, and 142 miles respectively. The cost of transmission of power to these places would be great because of the long lines required.

Utilization of power by an aluminium reduction works.

Regarding the question of utilizing the power in an aluminium reduction works the first question is that of

cost. It has not yet been ascertained what will be the actual cost per kilowatt-hour and at what price it could be sold to large consumers. Moreover, it remains to be seen whether the Rewa Durbar will agree to this scheme because its acceptance would mean that a large area under cultivation would have to be abandoned. There is, further, the question of compensation which may lead to complications Even if these difficulties were smoothed down, there remains the question of transport of material from Sutna to Poorwa and Chachai. There is, at present, a good metalled road from Sutna to Rewa. Between Rewa and Chachai there is only a village path. The question of constructing a railway from Sutna to Rewa and thence to Poorwa would, therefore, have to be considered. The scheme will, under these circumstances, take a long time to mature. Whether it would be feasible to get power at 0·2 anna per unit, is a doubtful point but supposing that it could be done, the charges for 23,000 k w. hours required in the production of 1 ton of aluminium would be Rs. 287. Now in the scheme of producing the power by steam-driven turbo-generators at Burhar the cost of coal, for power sufficient to produce 23,000 k.w., was found to be Rs. 155. Further, interest and depreciation on the one crore of rupees required for the steam-driven power plant would be Rs. 166 per ton of aluminium produced. To this must be added the cost of stores required for the power house and the charges for supervision which may be reckoned at Rs. 25 per ton. The total cost of 23,000 kilowatt-hours generated by a steam plant at Burhar would be Rs. 346. There would, therefore, be a saving of Rs. 59 per ton of aluminium produced, if hydro-electric power could be obtained at 0·2 anna per unit. However, if hydro-electric power were to

be used the alumina would have to be sent to Sutna, Rewa, or Poorwa for the purpose of reduction. As two tons of alumina would have to be sent from Burhar for every ton of aluminium produced at the reduction works, the freight charges would cost about Rs. 10 per ton of aluminium produced. The net saving would, therefore, be Rs. 49 per ton of aluminium.

Supposing that it was not found possible to supply power at 0·2 anna per unit and that the charge was 0·3 anna. In that case for the 23,000 k.w. hours the cost of power would be Rs. 431, that is, Rs. 85 more than that for power generated by the steam plant. The relative merits of electric power produced by steam and water have in this case to be judged by their cost alone. Unless the power generated by the falls could be supplied at 0·2 anna per unit, steam will hold its sway, at least in this particular instance.

XLIV. Generation of Power by a hydro-electric plant, the necessary water to be obtained by the creation of a large Artificial lake in a suitable place on the Maikala Hill range within Rewa territory.

That part of the Maikala Hill range which lies in Rewa territory runs in an approximately N.W. to S.E. direction for about 85 miles. The B N. Railway runs, more or less, parallel to this hill range from near Umaria to Amarkantak. The southern part of the range lying within Rewa territory is flat-topped and is known as Amarkantak plateau from the village of Amarkantak on which there stand a few sacred shrines. The general level of the plateau is about 3,000 feet above sea level, individual peaks attaining a height of more than 3,600 feet. The highest point is Badhargadh which is at an elevation of 3,860 feet above sea level.

The Sone, Nerbudda and Johilla Rivers.

Three rivers originate near Amarkantak—the Sone, Nerbudda, and Johilla. The Sone whose nominal source is the Sone-Bhadra falls over the eastern edge of the plateau and flows through the Pendra District till it again enters Rewa territory at 23° 6′ : 81° 59′. The Nerbudda, which has its source near Amarkantak, also leaves Rewa territory after flowing through it for $1\frac{1}{2}$ miles. For 40 miles it forms the boundary between Rewa State and Mandla District. Only the Johilla continues to flow through Rewa territory, and it is with this river that we are principally concerned regarding the scheme above mentioned, namely, the construction of an artificial lake in a suitable place on the plateau.

Suitable sites for the storage of water

A suitable site for a bund is one not far from the spot where the Gungauti Nadi meets the Johilla. At this point, the Johilla is about 37 miles distant from its source. Although ideal conditions exist in many parts along the river channel for the construction of a dam and storage of water, the chief difficulty seems to be about conducting the water to the lower levels. Near the junction of the Gangauti Nadi and the Johilla River this difficulty is not so great. The length of the aqueduct or pipeline would be from 5 to 6 miles long. A suitable site for a power station is near Amha (23° 5′ : 81° 26′). If we take the average height of water in the reservoir at 2,450 feet above sea level, the head available will be about 800 feet at Amha which is at an altitude of 1,650 feet The catchment area above the proposed site for a dam is about 220 miles. No figures are available for the annual rainfall in the hills. The average annual rainfall in the Sohagpur Tehsil (on the plains) is 52 inches. It is quite reasonable to suppose that the annual rainfall in the hills would be about 75 inches. Assuming the run off to be 35% we get :—

$$\text{Run off} = 220 \times 27{,}878{,}400 \times \frac{75 \times 35}{12 \times 100}$$
$$= 13{,}416 \text{ million cubic feet.}$$

This is the average quantity of water which could be impounded

The average discharge would be as follows :—

$$\text{Discharge} = \frac{220 \times 27{,}878{,}400 \times 75 \times 35}{12 \times 100 \times 365 \times 24 \times 60 \times 60} \text{ cusecs.}$$
$$= 4{\cdot}25 \text{ cusecs}$$

$$\text{Horse Power available} = \frac{425 \times 800}{11}.$$
$$= 30{,}909.$$

Other sites for a bund

As said before there are some very good sites for a bund further down the river. One such site is to the north-west of Keri (23° 5′ : 81° 18′) across the deep channel of the Johilla River. The pipe-line in this case would be at least 8 miles in length If this part was carefully surveyed and levels taken at different points below the river it would be ascertained if a head of 600 to 800 feet could be obtained along the natural channel of the river instead of carrying the water over the eastern edge of the plateau. There are other parts further down the river where a bund could easily be constructed

The above scheme is put forward by the writer. The possibility of storing water, in suitable parts on the Maikala Hills, for the generation of power has not yet received the attention of the Hydro-Electric Survey of India and the sites mentioned above have not yet been examined.

APPENDICES.

Appendix II.

Table showing the Production of Corundum in Rewa State from 1901 *to* 1921.

Official Year.	Maunds.
1901–02 ..	3,496
02–03 ..	602
03–04 ..	168
04–05 ..	—
05–06 ..	1,428
06–07 ..	250
07–08 ..	506
08–09 ..	207
09–10 ..	3,865
10–11 ..	1,317
11–12 ..	183
12–13 ..	1,001
13–14 ..	16
14–15 ..	417
15–16 ..	923
16–17 ..	329
17–18 ..	798
18–19 ..	3,210
19–20 ..	—
20–21 ..	1,612

Table showing the Production of Corundum in India.

Calendar Year.	Quantity (Short tons)	Value in £s.
1898	380 ..	—
1899	44 .	171
1900	69 ..	225
1901	82 ..	357

Calendar Year.	Quantity (Short tons).	Value in £s
1902	28	108
1903	—	—
1904	—	—
1905	53	—
1906	—	—
1907	28	—
1908	—	—
1909	41	196
1910	245	1 064
1911	309	2.226
1912	386	1 413
1913	398	2,022
1914	118	447
1915	62	277
1916	1,868	2,783
1917	2 071	3,875
1918	2,014	4.106
1919	706	5,347
1920	210	575

Appendix III.

Table showing the Quantity of Fire-clay produced at Chandia on the Katni-Bilaspur line.

Year.	Quantity.
	Tons.
1915	133
1916 .. .	1,195
1917	2.048
1918 .. .	4,217
1919 .. .	4,510
1920	2,546
1921	10,203

Table showing the Production of Sandstone at Pathat Quarries in Teonthar Tehsil, Rewa State (near Shankergadh Railway Station on the E.I. Ry.) from 1916 *to* 1920.

Year.	Quantity
	Cubic feet
1916	49,000
1917	55,600
1918 . ..	50,000
1919	32.600
1920	41,400

NOTE.—Much of the sandstone produced is used for building purposes while a small part is made into millstones for which there seems to be a fair demand.